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Tracing financial innovation diffusion and substitution trajectories. Recent evidence on exchange-traded funds in Japan and South Korea

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ABSTRACT

Since the rapid growth of the popularity of ETFs, the potential substitution between innovative financial products, exchange-traded funds (ETFs), and traditional investment funds (open-end and closed-end funds) is recognized as one of the most-discussed issues in the financial industry. This is the first study to empirically verify and compare the diffusion and substitution of ETFs using monthly data on their assets in two selected countries. The main aim of this paper is to provide in-depth insights into the development of innovative financial products available in two Asian economies: Japan and South Korea. The empirical study uses monthly total net assets data for 2004–2017. Our methodological framework combines models of innovation diffusion and technological substitution. The results reported in the study show that in both countries the diffusion of ETFs has occurred. The rate of diffusion and the phase of growth reached differed – in Japan the ETF market was in the early exponential growth stage, whereas in South Korea it was closer to achieving the expected maximum saturation. The results of the substitution analysis between the largest category of the innovative funds – equity ETFs and equity open-end funds clearly demonstrate that the process of "switching" from equity open-end funds into ETFs may be easily traced in both countries. Substitution processes were, however, gradual and reversals of the trajectories were noticed.

1. Introduction

Exchange-traded funds (ETFs) are recognized financial innovations and they are pervasively impacting and transforming financial markets (Deville, 2008, Gastineau, 2010, Agapova 2011, Hill et al., 2015). They are easy to use and have rapidly gained growing popularity among investors (Ferri, 2009; Gastineau, 2010; Madhavan, 2016) – they have become competing products for well-established, traditional investment funds, i.e. open-end and closed-end funds. Until recently, due to highly similar investment aims and groups of users, ETFs were mostly considered substitutes for only one type of traditional funds – index funds. The increasing popularity and complexity of the available ETFs has led to growing interest among various participants of financial markets. ETFs are now compared not only to index funds but also to other types of traditional funds, e.g. active funds. The discussion of the relative benefits of ETFs versus other types has over the last few years been one of the key debates in the investment industry and financial research.

Dynamics of the diffusion of ETFs and substitution between ETFs and traditional investment funds constitutes a new research field – the evidence is scarce and fragmented. Moreover, the only previous research of this type which covered Japanese and South Korean ETF markets (Lechman and Marszk, 2015), due to limited data availability, was conducted using annual observations which do not fully capture the trajectory of these processes, and did not include substitution analysis. Moreover, it did not analyse in detail the changes on those markets. Our calculations are based on more recent monthly data and values at country level are aggregated using individual fund-level data (for several thousand funds). Therefore, they show accurately the cumulated size of selected categories of investment funds in both countries. Apart from open-end funds, we consider also closed-end funds as alternatives to ETFs which were omitted in the previous research on the diffusion of innovative funds.

Fast spread of financial innovations has been observed in Asian countries and therefore this analysis covers Japan and South Korea, which are both countries with rapidly growing size of the local ETF markets (other Asian ETF markets are rather unique (e.g. Hong Kong)

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or much smaller (e.g. India)). This allows the comparison of diffusion and substitution trajectories of innovative financial products in two economies – one of them, Japan, being among the world pioneers in terms of the ETF's inception (first ETF was launched in 1995 – Japan was the first country outside North America with the ETF market), and second, South Korea, which initially lagged behind but later experienced very dynamic expansion of the innovative funds. We also trace financial substitution effects between ETFs and their open-end funds counterparts in the oldest, and at the same time, the most significant category of ETFs, i.e. funds based on equities.

As suggested in the literature, ETFs may influence financial systems in various ways and impact their stability (Foucher and Gray, 2014; Kosev and Williams, 2011), causing or magnifying some threats to the financial stability of particular sectors (at micro level) or entire system (at macro level); we therefore discuss the key issues, and evaluate their relevance for Japanese and South Korean financial systems.

Significance of the research on ETFs may also be framed in the more general context of innovations introduced in the financial system in the recent years, usually inextricably linked with adoption of information and communication technologies (ICT). Key recent system-broad innovations facilitated through the technological change in the financial industry include concepts such as the broadly discussed FinTech (Financial Technology) or cryptocurrencies (e.g. most acknowledged bitcoin), as well as relatively less recognized RegTech (new technologies used to meet increasingly complex regulatory requirements).

Innovations may be observed in all parts of the financial system but some of the most evident were introduced in the banking sector. They include, inter alia, electronic payments, mobile and online banking services for retail customers, processing of financial transactions through electronic systems, and online corporate banking services (Diaz-Rainey et al., 2015). The backbone of many modern financial innovations is big data which means that the daily operations of growing number of financial institution are based on databases gathered each day from varied resources (Chauhan et al., 2017). Another important recent financial innovation (linking in fact new developments in financial institutions and on financial markets) is robo-advisors, i.e. highly automated advisory services (with very limited human interaction) which support investment management and are available online (Hill, 2018).

Innovations in financial markets have various forms. Most importantly, they may change the ways of trading by decreasing the role of floor-based exchanges and boosting the development of electronic systems by removing some of the barriers for incumbents trying to establish such platforms. It may have profound consequences such as increased integration of capital markets (Panourgias, 2015) or new business models of the exchanges, with new categories of financial instruments available (Ernkvist, 2015); another effect may be increased cross-listing of securities (Calamia et al., 2013). An even deeper result of technological change on the financial markets is the introduction of trading platforms in which the role of human traders is severely limited, i.e. algorithmic and high-frequency trading (HFT). The impact of these low-latency trading activities has still not been fully verified; some of the threats listed in the literature include inadequate control over such operations and risk of large and irreversible losses (Kauffman et al., 2015), or, more generally, higher fragmentation and volatility of trading (Essendorfer et al., 2015). Due to their novel features, ETFs have become one of the most prominent types of innovations in the area of both financial markets and institutions, as evidenced by their assets or turnover of their shares, especially in countries such as United States or Mexico (Kaur et al., 2017). However, despite its significance, the substitution dynamics of ETFs (in relation to comparable investment funds) had not been robustly and formally explored in the literature which substantiates the contribution of this paper. It should be added that positive feedback between different types of financial innovations may be observed, for example, robo advisers usually employ ETFs for the user's portfolio.

The main aim of this paper is to provide in-depth insights into the issues associated with the development of selected investment funds in two Asian countries: Japan and South Korea, over the period 2004–2017 (last available data are from August 2017). In this research special emphasis is put on the development patterns of ETFs, as this area is still poorly explored in empirical literature.

To ensure a logical flow in the study we define three major empirical goals:

1. To develop the diffusion trajectories of financial innovations (ETFs) and examine the dynamics of the process in Japan and South Korea;
2. To provide long-term predictions of financial innovation developments in the countries examined and to attempt to establish the possible future paths of ETF market developments in these countries;
3. To trace the unique process of substitution between equity ETFs and equity open-end funds.

In order to reach the stated aims, we first apply descriptive statistics to unveil the basic changes and trends in ETF market development between 2004 and 2017; second, we deploy a methodological framework employing innovation diffusion models, which allows for detailed analysis of ETF market development patterns, description of the past dynamics of the process, and predictions of future changes; we also use technological substitution models in order to analyse substitution between various investment funds. Additionally, we examine the impact of ETFs on the financial systems in the countries studied. With this aim, we investigate the structure of the ETF markets in the two countries analysed.

The results reported in the study show that the ETF market has been developing both in Japan and South Korea - diffusion of ETFs has occurred. One of the key factors contributing to the ETF market development was the launch of ETFs which offer investors modified returns. In Japan, ETF market development has also been influenced by the Japanese central bank. The rate of diffusion and the phase of growth reached differed in the two countries – in Japan by the end of the considered period the ETF market was still in the early fast growth stage, whereas in South Korea it was closer to achieve the expected maximum saturation. The results of the substitution analysis clearly demonstrate that the process of "switching" from equity open-end funds into equity ETFs may be easily traced in both the countries examined. Our results suggest that it is difficult to draw conclusions about the potential impact of ETFs on the local financial systems because, on the whole, ETF markets were too small to influence them significantly.

The remainder of this paper is structured as follows. The second section presents the theoretical background and explains issues associated with ETFs: their basic features, comparisons with open-end and closed-end funds, and their impact on financial systems. The third section outlines the methodological setting and the fourth presents our data sources. Section five is divided into four parts. The first of these is an overview of the ETF markets in Japan and South Korea with preliminary descriptive evidence on ETF market development. The second part discusses the major empirical results obtained from our diffusion models, the third outlines results of the substitution analysis and the fourth evaluates the impact of ETFs on the financial systems of the two countries. Section sixth concludes.

2. Theoretical background

2.1. Exchange-traded funds: basic features

Exchange-traded funds (ETFs) are innovative investment funds and in their basic form they can be defined as baskets of securities traded on a stock exchange (similar to, e.g., the shares of listed companies), usually through brokerage firms (Ferri, 2009). They were launched on the financial markets in the 1990s and 2000s and their prices closely replicate (i.e. track) the prices of financial assets, in most cases stock market indexes (Hehn, 2005). Shares (units) of ETFs can be traded during stock exchange trading hours at prices determined by the market participants. The prices of ETF shares are usually close to their net asset value.

The ETF market can be divided into two segments: primary and secondary (Hill et al., 2015). ETF shares are created or redeemed on the primary ETF market in the course of transactions between a managing company (the fund's provider) and authorized participants (large financial institutions). These transactions can involve delivery of the underlying assets (in the case of physical ETFs) or cash (in the case of synthetic ETFs, i.e. ones based on derivatives, which are popular mostly in Europe) in exchange for the ETF shares. It means that the number of ETF shares is not fixed and is determined by the demand among investors.

The secondary market consists of transactions on stock exchanges involving the sale or purchase of ETF shares between market participants (authorized participants and individual or institutional investors) without any interaction with the provider. The specific features of the trading process depend on a number of factors, including the legal form of the ETF, the replication method applied by the fund managers and the assets tracked. Investors may purchase or sell the shares of ETFs through their brokerage accounts, like stocks of listed companies.

One of the key concepts for ETFs and other investment funds (discussed in Section 2.2) is net asset value (NAV). It is calculated by estimating the market value of the assets, subtracting the liabilities and dividing the outcome (total net assets) by the number of units. In case of ETFs it is particularly important in the context of arbitrage mechanism.

Arbitrage mechanism may be perceived as one of the key innovative features of ETFs. It is based on the relationship between primary and secondary ETF market and the market for the underlying (tracked) assets. If price of the fund's shares deviates from their NAV, then authorized participants have an opportunity to gain profits from the arbitrage operations:

– When price of the shares is lower than their NAV, they can buy the shares and exchange them for the assets included in the basket required by the fund's provider;
– When price of the shares is higher than their NAV, they can deliver the underlying assets and exchange them for the fund's shares.

As a result of the above-mentioned transactions, authorized participants receive underpriced assets or shares of the fund which can be sold for a profit. On the market-broad basis, it means that ETF tracking errors (deviations of the returns on ETFs from the returns on the benchmark) are usually kept low due to upward pressure on the prices of the underpriced assets or shares and reverse mechanism in case of overpriced ones (Ben-David et al., 2017). For most ETFs benchmark is simply some kind of index (e.g. describing behaviour of the stock or bond market).

2.2. Comparison between exchange-traded funds and conventional investment funds

The growing popularity of ETFs in the last decade has mostly resulted from the benefits they offer to investors compared to traditional investment funds, especially the subcategory of open-end funds with aims similar to ETFs – index funds. However, due to growing diversity of the innovative funds this discussion may be extended to comparisons between the entire categories of ETFs and open-end funds. Moreover, ETFs offer certain advantages versus another type of investment funds, i.e. closed-end funds, which will also be covered in our discussion. The comparison of three discussed categories of investment funds has been summarized in Table 1.

Open-end funds (also labelled "mutual funds") are in most countries the largest category of investment funds, particularly in terms of assets. Investment Company Institute (2017) defines them as a type of investment funds in which managers buy and manage certain portfolio of assets; managers are constrained by the financial objective stated in the fund's policy. The name of this group indicates its key attribute, i.e. readiness of open-end funds to sell or redeem their units (buy back previously issued units) at the investor's request, at their current NAV. This creation/redemption process is conducted directly between the fund or related entities and investors, not on separate (primary) market as in case of ETFs.

Open-end funds and ETFs (to lower extent closed-end funds) can be classified according to various criteria but two most basic distinctions are based on the type of underlying assets (equity and fixed income funds are the main groups) and investing strategy in relation to the benchmark (active versus passive funds as the two fundamental groups). In active funds, the aim of managers is to reach the highest return in reference to the benchmark, after controlling for the risk level.

Table 1
Main differences between ETFs, open-end funds and closed-end funds.
Source: own compilation based on Hehn (2005), Deville (2008), Ferri (2009), Agapova (2010), Gastineau (2010), *Value* Line (2010), Aggarwal and Schofield (2014), BlackRock (2015), Hill et al. (2015), Lechman and Marszk (2015), Baker et al. (2016), Madhavan (2016), Nikbakht et al. (2016), Ben-David et al. (2017), Investment Company Institute (2017).

Feature	ETFs	Open-end funds	Closed-end funds
Product range	Broad, many asset classes; both passive and active funds but equity passive funds remain the dominant category. Leveraged and inverse funds available	Very broad	Highly limited
Channels of distribution/trading venue	Stock exchange or similar	Various channels (e.g. investment professionals), unavailable on stock exchanges	Stock exchange or similar
Valuation of fund's units	Dual: NAV calculated by the fund, secondary market price depends on demand and supply (and actions of authorized participants)	NAV calculated by the fund	Dual: NAV calculated by the fund, secondary market price depends on demand and supply
Portfolio transparency	High, portfolio composition usually published daily	Limited, portfolio composition usually published monthly or quarterly	Limited, portfolio composition usually published monthly or quarterly
Number of units outstanding	Changing	Changing	Usually fixed
Market structure	Primary and secondary market	No separation	Primary (very limited) and secondary market
Popularity	Growing, available in many economically-advanced countries and some emerging economies	High, available in most countries	Low (and decreasing), available in some countries

In contrast, in passive funds, tracking (i.e. following) the performance of the defined benchmark is the fund's aim which means that managers attempt to minimize the tracking error. Index funds, which track the return on certain indexes, are main type of passive open-end funds; they are similar to the most popular passive ETFs. However, in the last few years, ETF category has expanded with the launch of enhance indexing ("smart beta") or even active funds (Nikbakht et al., 2016); the most recent innovation includes exchange-traded managed funds which combine the features of active ETFs and open-end funds (Madhavan, 2016). Other important innovation are leveraged and inverse ETFs (discussed in Section 2.3).

The fundamental difference between open-end funds and ETFs is that, in contrast with ETFs, the units of open-end funds are not traded on a stock exchange or similar trading venue. This means that they have different channels of distribution. Units of open-end funds are sold through various channels such as financial advisers or bank offices; broker-dealer distribution is not used as the funds are not listed. Another serious consequence is significant difference in terms of valuation. Even though for both categories NAV is determined by the fund, usually once a day, only for open-end funds it is the binding price in the creation/redemption operations with investors – for ETFs NAV is important indicator on the primary market yet on the secondary market (used by the vast majority of investors) the price depends on the interaction of market demand and supply and is determined continuously (Ferri, 2009; Gastineau, 2010). It is also influenced by the arbitrage activity of authorized participants. Furthermore, ETFs are more transparent – the composition of their portfolio is published daily (with some rare exceptions) whereas most open-end funds disclose their holdings much less frequently: once a month or quarter.

It should be underlined that the comparison cannot be one-sided as there some relative advantages of open-end funds versus ETFs (Baker et al., 2016):

– many pension plans or other similar institutions are prohibited from using ETFs (limitations on the use of open-end funds are less strict);
– the range of available open-end funds is much broader, particularly in the non-equity and active category;
– awareness of the ETFs features and possible applications among most investors is still much lower than their knowledge about open-end funds.

Finally, the comparison of passive ETFs and passive open-end funds (i.e. mostly index funds) shows a number of relative advantages of the innovative funds, which stem above all from the innovative ETF creation and distribution mechanisms: lower tracking errors and lower tracking costs, and higher tax efficiency in some countries (e.g. the USA) (Agapova 2011, Aggarwal and Schofield, 2014, BlackRock, 2015, Lechman and Marszk, 2015).

Closed-end funds are another type of investment fund whose distinguishable attribute is issuance of a fixed, predetermined number of units (lack of open-end structure or creation and redemption mechanism) which are listed and traded on stock exchanges (like listed stocks or bonds) (Investment Company Institute, 2017). In this aspect the shares (units) of closed-end funds resemble the shares of ETFs – both have primary and secondary market. However, there is no arbitrage mechanism similar to ETFs (no activity of authorized participants) which makes the tracking errors of closed-end funds larger due to very low primary market activity. Closed-end funds are highly limited in terms of offered product range due to the various legal and technical restrictions (Value Line, 2010). Closed-end funds are available in a limited number of countries and even there their popularity seems to be diminishing, particularly since the emergence of ETFs (see Section 5.3 for discussion regarding substitution between these two categories in Japan and South Korea).

2.3. Exchange traded funds – impact on the financial system

The impact of the surging popularity of ETFs in relation to traditional investment funds (above all open-end funds) should be considered in a broad perspective, not only from the point of view of single investors or financial institutions. Growing ETF markets may influence the stability of financial systems. Some of the most notable potential transmission mechanisms and risk factors are listed below (Amenc et al., 2012; Diaz–Rainey and Ibikunle, 2012; Foucher and Gray, 2014; International Monetary Fund, 2011; Kosev and Williams, 2011; Ramaswamy, 2011; Rubino, 2011):

1. *Liquidity risk*. Liquidity of ETF shares and liquidity of underlying assets are strongly linked due to activities of the primary and secondary ETF market, particularly arbitrage mechanism. Possible disruptions in this mechanism, which facilitates one of the key advantages of passive funds, i.e. low tracking error, may be caused by various factors, including regulatory constraints imposed on ETF providers (Foucher and Gray, 2014). As a result, prices of the ETF shares may deviate significantly from their NAV (and thus also from prices of the underlying assets) for a prolonged period. In an extreme scenario, it can lead to sudden large transactions of investors and breakdown of the ETF market. If the ETF market is big in relation to the underlying assets market, then the breakdown could spill over between the interconnected markets; it may also affect markets for other ETFs.
2. *Lack of transparency*. Some ETFs have complicated mechanisms employed by their providers in order to track certain assets; it applies principally to leveraged and short ETFs which are subcategories of synthetic funds based on swap contracts or other derivatives that offer magnified or reverse performance of the benchmark (Madhavan, 2016). It may hinder the assessment of their risk, both for their users and institutions responsible for financial stability. Problems with stability risk evaluation could be further compounded in case of funds listed on many exchanges in more than one country.
3. *Risk of contagion and shock transmission between countries*. This risk concerns transmission of shocks (e.g. sudden changes in the prices) between ETFs traded in one country and their underlying assets which are listed in other countries (an example of such fund would be ETF listed in the United States with exposure to Japanese equities). The seriousness of this problem may be exacerbated by cross-listings and regulatory differences. However, links established through the operations of such funds may also lead to higher financial openness and, consequently, to increased factor productivity and amount of capital available in the economy (effects of financial openness had been analysed in, e.g., Bekaert et al. (2011)).
4. *Negative impact on commodity markets*. Growing interest in ETFs which track the prices of basic commodities (for instance food and energy) may lead to amplified speculation and increasing inflation.

The threshold level for the emergence of the negative outcomes outlined above has still not been identified. Most authors agree that the scale of potential threats will increase with the growth of the ETF market (Aggarwal and Schofield, 2014; Naumenko and Chystiakova, 2015).

3. Methodological framework

The methodological framework we adopt allows for identification of the time evolution of the processes reported in the financial markets examined regarding, inter alia, ETF diffusion. Therefore, apart from standard descriptive statistics, we use innovation diffusion models (Geroski, 2000, Rogers, 2010, Kwasnicki 2013, Lechman, 2015), which are applied to approximate ETF diffusion trajectories and reveal projected future ETF development patterns. An analogous approach to identification of ETF market evolution is employed by Lechman and Marszk (2015), who analyse ETF diffusion paths in selected emerging markets.

To uncover ETF market development patterns we use the empirical framework of the innovation diffusion model provided in the influential works by, inter alia, Mansfield (1961) and Dosi and Nelson (1994), who analysed the phenomenon adopting the evolutionary dynamics concept. The concept may be mathematically expressed as a logistic growth function, which if written as an ordinary differential equation is as follows (Meyer et al., 1999):

$$\frac{dY_x(t)}{dt} = \nu Y_x(t) \tag{1}$$

If $Y(t)$ denotes the level of variable x, (t) is time, and ν is a constant growth rate, then Eq. (1) explains the time path of $Y(t)$. If we introduce mathematical constant e into Eq. (1), it can be reformulated as:

$$Y_x(t) = \eta\, e^{\nu t}, \tag{2}$$

or alternatively

$$Y_x(t) = \nu\ \exp \eta\, t, \tag{3}$$

with notation analogous to Eq. (1) and η representing the initial value of x at $t = 0$ (Meyer et al., 1999). The simple growth model is pre-defined as exponential. Thus, if left to itself x will grow infinitely in geometric progression. Indiscriminate extrapolation of $Y_x(t)$ generated by an exponential growth model may lead to unrealistic predictions, as due to various constraints systems do not grow infinitely (Meyer, 1994). Therefore, to solve the problem of "infinite growth", a "resistance" parameter (Kwasnicki 2013) is added to Eq. (1). This modification introduces an upper "limit" into the exponential growth model, giving the original exponential growth curve a sigmoid shape. Formally, the modified version of Eq. (1) is a logistic differential function, defined as

$$\frac{dY(t)}{dt} = \alpha Y(t)\left(1 - \frac{Y(t)}{\kappa}\right), \tag{4}$$

where the parameter α is the rate of growth, κ denotes the imposed upper asymptote that arbitrarily limits the growth of Y.

As mentioned, adding the resistance parameter to the exponential growth equation generates an S-shaped trajectory (see Fig. 1). The 3-parameter logistic differential equation, Eq. (4), can be re-written as a logistic growth function, taking non-negative values throughout its path:

$$N_x(t) = \frac{\kappa}{1 + e^{-\alpha t - \beta}}, \tag{5}$$

or, alternatively

$$N_x(t) = \frac{\kappa}{1 + \exp(-\alpha(t - \beta))}, \tag{6}$$

where $N_x(t)$ stands for the value of variable x in time period t. Parameters in Eqs. (5–6) represent the following: κ–the upper asymptote, which determines the limit of growth, also labelled the "carrying capacity" or "maximum (potential) saturation" level; α–the growth rate, which shows the speed of diffusion and determines the "specific duration" parameter, defined as $\Delta t = \frac{\ln(81)}{\alpha}$; β parameter determines the exact time (T_m) – midpoint, when the logistic pattern reaches 0.5κ. By using Δt it is easy to approximate the time needed for x to grow from 10%κ to 90%κ. The midpoint (β) describes the point in time at which the logistic growth starts to level off. Mathematically, the midpoint is the inflection point of the logistic curve. Incorporating Δt and T_m into Eq. (6) produces (see: Kudryashov, 2013):

$$N_x(t) = \frac{\kappa}{1 + \exp\left[-\frac{\ln(81)}{\Delta t}\left(t - T_m\right)\right]}. \tag{7}$$

We use the above methodological framework as the innovation diffusion model in our analysis. During the first part of the analysis we assume that the growing value of total net assets of ETFs represents their

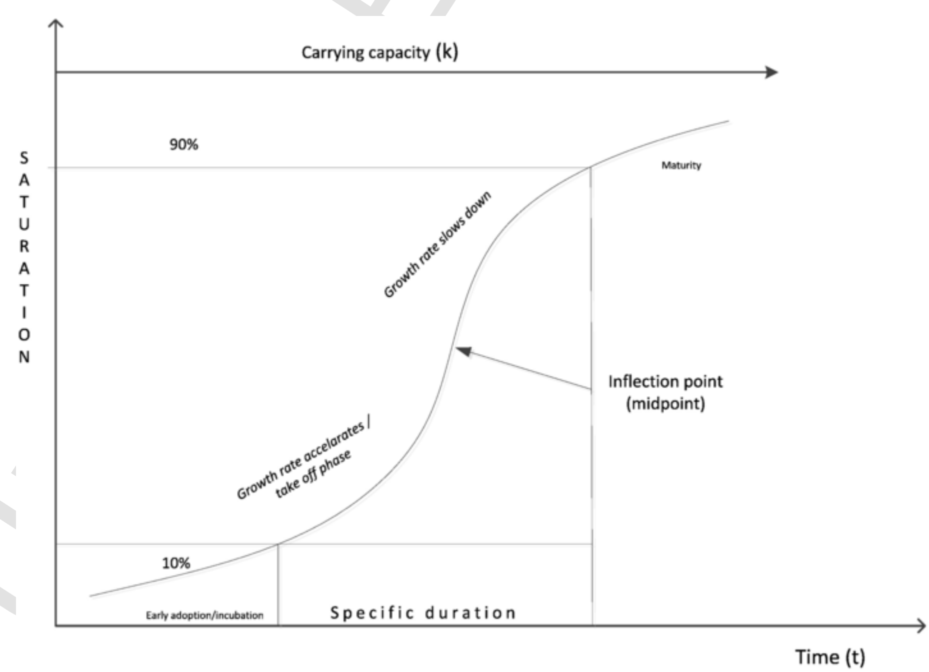

Fig. 1. S-shaped diffusion trajectory. Theoretical specification. Source: Lechman (2015).

diffusion in local financial markets. However, in the main part of our analysis we assume that the process of growth of the ETF share in the total net assets of investment funds (apart from ETFs, they include open-end funds and closed-end funds) is analogous to the process of diffusion of innovations across heterogeneous socio-economic systems. Henceforth, we treat ETFs as innovations, which due to "word of mouth" (Geroski, 2000) and emerging network effects are gradually adopted by an increasing number of investors (users). We also rely on the basic assumption that investors (users) in financial innovations (ETFs) may freely contact each other, leading to broader adoption of the innovations by "non-investors" ("non-users"), i.e. people either not previously using ETFs or choosing other similar options. The process of growth in the adoption of financial innovations (ETFs) is effectively enhanced by unbounded access to information ensured by, for instance, broad adoption of information and communications technologies. In short, we assume that ETFs diffuse on financial markets and gain a growing share in the total net assets of comparable investment funds (ETFs, open-end funds and closed-end funds). Considering the basic version of the 3-parameter logistic growth model as defined in Eq. (6), we presume that $N_x(t) = ETF_i(t)$ demonstrates changes in the ETF share in the total net assets of investment funds over time t in country i. Put differently, it shows changes in the level of country i's saturation with ETFs on investment funds market. The parameter κ is represented as κ_i^{ETF}, which shows the ceiling (upper asymptote/system limit) for the process of ETF diffusion on financial markets. The κ_i^{ETF}estimated denotes the potential share of ETFs in the total net assets of investment funds in the financial system analysed in country i, but under the rigid assumption that the ETF diffusion (development) trajectory follows the sigmoid pattern generated by the logistic growth equation. Next, the parameter α (as in Eq. (6)) is represented as α_i^{ETF}, which shows the speed of ETF diffusion in the financial system analysed in country i. Hence, the estimated parameter α_i^{ETF}represents how fast the ETF share in the total net assets of investment funds is increasing in the market. Moreover, we can use the parameter $\alpha_i^{ETF}$to calculate the "specific duration," defined as $\Delta t = \frac{\ln(81)}{\alpha_i^{ETF}}$, which represents the time needed to pass from $\kappa_i^{ETF} = 10\%$ to $\kappa_i^{ETF} = 90\%$. The parameter β is expressed as β_i^{ETF}, and its estimated value indicates the midpoint, $T_{mi}{}^{ETF}$, which is the exact time when 50% of κ_i^{ETF} is reached. Hence, $T_{mi}{}^{ETF}$ shows the time (year/month) when the process of ETF diffusion is at the half-way stage if we assume that it is heading toward κ_i^{ETF}. Henceforth, the modified specification of Eq. (6) will thus be

$$ETF_i(t) = \frac{\kappa_i^{ETF}}{1 + \exp\left(-\alpha_i^{ETF}\left(t - \beta_i^{ETF}\right)\right)}, \tag{8}$$

with notations as explained above.

To be more specific, in the analysis we estimate the following country-specific logistic growth models:

$$ETF_{Jap}(t) = \frac{\kappa_{Jap}^{ETF}}{1 + \exp\left(-\alpha_{Jap}^{ETF}\left(t - \beta_{Jap}^{ETF}\right)\right)} \tag{9}$$

and

$$ETF_{Kor}(t) = \frac{\kappa_{Kor}^{ETF}}{1 + \exp\left(-\alpha_{Kor}^{ETF}\left(t - \beta_{Kor}^{ETF}\right)\right)}, \tag{10}$$

where, $ETF_{Jap}(t)$, $ETF_{Kor}(t)$ stand for ETFs share in respective countries in period t; $\kappa_{Jap}{}^{ETF}$ and $\kappa_{Kor}{}^{ETF}$represent the upper asymptote, the growth limit of ETFs in the Japanese and South financial systems; $\alpha_{Jap}{}^{ETF}$ and $\alpha_{Kor}{}^{ETF}$are the rate (speed) of diffusion of ETFs; and $\beta_{Jap}{}^{ETF}$ and $\beta_{Kor}{}^{ETF}$ are the midpoints of the respective ETF diffusion patterns – the exact time (year and month) when 0.5κ is achieved. The parameters in Eq. (8) can be estimated using ordinary least squares (OLS), maximum likelihood (MLE), algebraic estimation (AE), or nonlinear least squares (NLS). However, Satoh (2001) suggests that NLS returns the relatively best predictions, as the estimates of standard errors (of κ_i^{ETF}, α_i^{ETF}, β_i^{ETF}) are more valid than those returned from estimation using other methods. Adoption of NLS avoids time-interval biases, which occur in the case of OLS estimates (Srinivasan and Mason, 1986). However, the main disadvantage of the NLS procedure is that the estimates of the parameters may be sensitive to the initial values in the time-series adopted.

In addition, we use the technological substitution model framework that was initially developed by Fisher and Pry (1972) and then adopted in various studies, such as Kucharavy and De Guio (2011) and Miranda and Lima (2013). The process of technological substitution may be defined as a gradual replacement of "old" technologies by "new" ones. In a way it resembles competition between the "old" and "new" technology, with the "old" technology being the initially dominant competitor in the market and the "new" "invading" one fighting for a growing market share (Lechman, 2015; Morris and Pratt, 2003). The technological substitution model (also labelled logistic substitution model) explains the competitors' changing market shares (fractions) (Wang and Lan, 2007). As Fisher and Pry (1972) and Kucharavy and De Guio (2011) state, the evolutionary process of technology diffusion passes through three characteristic phases: a logistic growth phase, when growth rates are initially slow; an exponential growth phase, in which there is a rapid diffusion of the technology; and finally the saturation phase, when the technology reaches its maximum market share and thus follows a non-logistic pattern. Once the market is saturated, the technology may begin fading away from the market if it is gradually substituted by a new emerging technology (Marchetti and Nakicenovic, 1980; Nakicenovic, 1987). Technically, the technological substitution model explains changing shares in the market that competitors obtain, and it relies on the assumption that the total sum of users of the two competing technologies is fixed. In our work we follow the methodology developed by Blackman (1971) and Marchetti and Nakicenovic (1980), who formalized the original technological substitution model developed by Fisher and Pry, and use a three-parameter logistic substitution model allowing the behaviour of two competitors along the time trajectory to be modelled.

Consider a competitive system and consider a technology substitution model where only two different technologies are replacing each other. Assume that N_i represent the users of the two technologies, so that the share of the population using technology i at time t is (Lechman, 2015)

$$\frac{N_i(t)}{N} \tag{11}$$

Additionally, we follow Morris and Pratt (2003) and assume that the number of users is fixed and each deploys one of the two available technologies. This implies the constraint

$$f_i(t) + f_j(t) = 1, \tag{12}$$

where i and j are competing technologies.

As Kwasnicki (1999) shows, the technologies analysed follow a logistic growth trajectory expressed by:

$$f_i(t) = \frac{\kappa}{1 + \exp(-\alpha(t - \beta))}. \tag{13}$$

To calculate the market share ($y_i(t)$) possessed by technology i we adopt a Fisher-Pry transformation (1972), so that Eq. (12) yields

$$y_i(t) = \ln\left[\frac{f_i(t)}{1 - f_i(t)}\right]. \tag{14}$$

If

$$y_i(t) + y_j(t) = 1 \tag{15}$$

is true, the market share of technology j in the non-logistic saturation phase is shown by

$$f_j(t) = 1 - \sum j \neq if_i(t). \tag{16}$$

For an economic interpretation, it is crucial to identify the times when substitution phases begin and end. With this aim, we follow Meyer et al. (1999), who show that the estimate of the time when the saturation phase stops is given by:

$$\frac{y_i''(t)}{y_i'(t)} \to \min. \tag{17}$$

Hence, once we have y_i and $y_i^{'}$, it is possible to estimate the two parameters of the logistic curve for technology i, which can be expressed as:

$$\Delta t_i = \frac{\ln(81)}{y_i'(t)} \tag{18}$$

and

$$T_{m_i} = \ln\left[\frac{\left(y_i(t) - \frac{\ln(81)}{\Delta t}\right)}{\frac{\ln(81)}{\Delta t}}\right]. \tag{19}$$

Δt_i is labelled "takeover" (Fisher and Pry, 1972) and it shows the time needed for technology $i^{'}$ to increase its market share from $y_i(t) = 0.1$ to $y_i(t) = 0.9$; and $T_{m_{is}}$ representsthe specific point in time when the substitution process is half complete. Thus, $y_i(t) = y_j(t) = 0.5$.

Fig. 2 graphically presents the mechanism behind the technological substitution. It shows the life cycles of the competing technologies, and three distinct phases are detectable: logistic growth, saturation and logistic decline. The intersection point is the specific time (i.e. the year) when the technological substitution process is half complete. Thus, the two technologies control 50% of the total market ($\rightarrow y_i(t) = y_j(t) = 0.5$)).

Following the theoretical framework presented above, we analyse the process of financial substitution which, as we claim, may be analogously analysed as a process of technological substitution. In our study we assume there are two different, and potentially competing, investment funds with each possessing a certain share of the market in country i. Hence, we may rewrite Eq. (15) as

$$f_i^{\delta}(t) + f_i^{\theta}(t) = 1, \tag{20}$$

where

$$f_i^{\delta}(t) = \frac{\kappa_i^{\delta}}{1 + \exp\left(-\alpha_i^{\delta}\left(t - \beta_i^{\delta}\right)\right)}, \tag{21}$$

and

$$f_i^{\theta}(t) = \frac{\kappa_i^{\theta}}{1 + \exp\left(-\alpha_i^{\theta}\left(t - \beta_i^{\theta}\right)\right)}. \tag{22}$$

In Eqs. (21 − 22) i denotes the country, while δ and θ represent two competing types of investment funds in a given country i. To identify the process of financial substitution, we adopt the theoretical framework described in Section 3 and assume that a given hypothetical market can be described as in Eq. (20): $f_i^{\delta}(t) + f_i^{\theta}(t) = 1$, where i denotes the country, δ is equity ETFs, and θ is equity open-end funds. We estimate the following models

$$\frac{\kappa_{Jap}^{\delta}}{1 + \exp\left(-\alpha_{Jap}^{\delta}\left(t - \beta_{Jap}^{\delta}\right)\right)} + \frac{\kappa_{Jap}^{\theta}}{1 + \exp\left(-\alpha_{Jap}^{\theta}\left(t - \beta_{Jap}^{\theta}\right)\right)} = 1, \tag{23}$$

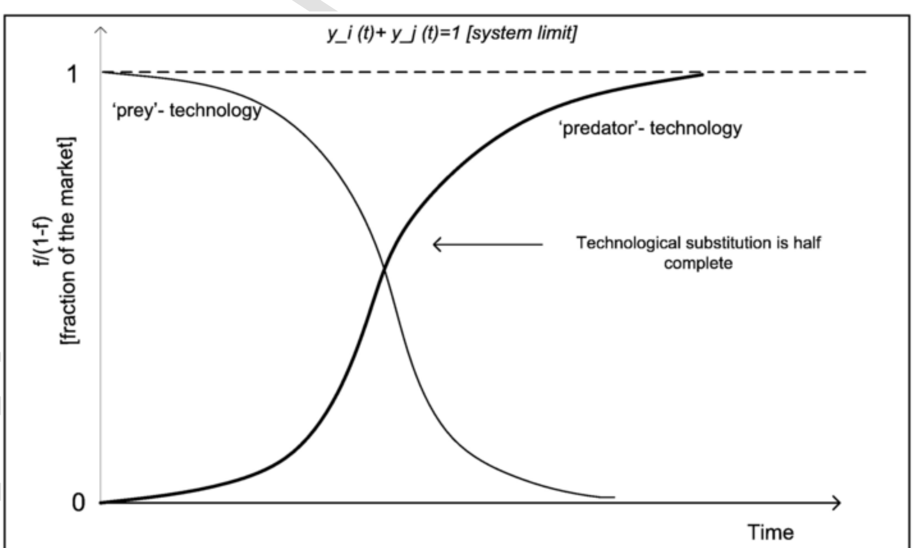

Fig. 2. Technological substitution process. Source: Lechman (2015).

for Japan, and for South Korea

$$\frac{\kappa^{\delta}_{Kor}}{1+\exp\left(-\alpha^{\delta}_{Kor}\left(t-\beta^{\delta}_{Kor}\right)\right)} + \frac{\kappa^{\theta}_{Kor}}{1+\exp\left(-\alpha^{\theta}_{Kor}\left(t-\beta^{\theta}_{Kor}\right)\right)} = 1, \tag{24}$$

Next, to calculate the market share $y_i^{\delta}(t)$ possessed by investment fund δ in country i we use the Fisher-Pry transformation and obtain Δt_i^{δ} denoting the "takeover" and determining the time needed for the type of fund δ to increase its market share from $f_i^{\delta}(t) = 10\%$ to $f_i^{\delta}(t) = 90\%$. Additionally, we estimate Tm_i^{δ} which represents the specific point in time when the substitution process is half complete, when $f_i^{\delta}(t) = f_i^{\theta}(t) = 0.5$.

4. Data

Our analysis concentrates on the two Asia-Pacific countries with the largest ETF markets (apart from China, which is difficult to evaluate due to various linkages between the stock exchanges in Hong Kong and Mainland China), namely Japan and South Korea. The time coverage is subjected to data availability, as a balanced data set is acquirable for both countries exclusively for the period January 2004–August 2017.

The investment funds database used in this study includes the dataset with monthly observations extracted from the Lipper database provided by Thomson Reuters. Market-broad estimates were calculated based on data on individual funds. We use data on both operating and currently inactive funds in order to account for e.g. liquidated funds. Our database covers following number of funds: for Japan 212 ETFs, 6073 open-end funds and 12 closed-end funds; for South Korea 348 ETFs, 16,613 open-end funds and 68 closed-end funds; it translates into more than one million, 1,139,505, individual non-zero observations from the selected time period. Before the inclusions in our dataset, raw data from the Lipper database were verified for the correctness (e.g. we checked data inputting errors)). It should be stressed that it is the first research on the development of ETF markets based on fund-level monthly observations aggregated into market-broad indicators.

All types of funds were classified using the most relevant criteria: ETFs were selected according to primary listing location, open-end funds according to their domicile, for closed-end funds we chose all funds listed on the exchanges in particular country. The most important financial indicators used to achieve the stated aims are total net assets (in USD millions) of selected investment funds (i.e. total assets minus liabilities) in Japan and South Korea: ETFs, open-end funds and closed-end funds, labelled together as "investment funds". We do not include other types of investment funds (if available on the local market) in our analysis due to their limited comparability to ETFs.

5. Results

This section describes the results of our empirical research. First, it develops and discusses the country-specific diffusion trajectories of financial innovations (ETFs) and examines the dynamics of the process in Japan and South Korea. Second, it provides long-term predictions of the financial innovation development in the countries examined, attempting to establish the possible future path of ETF market development. Third, it demonstrates the unique process of substitution between ETFs and similar investment funds, i.e. open-end funds and closed-end funds, again in Japan and South Korea. Finally, we briefly examine the impact of ETF market development on the financial systems in these countries. ETF market development as discussed in this text is understood in two ways: as the increase in the value of total net assets of ETFs (in USD millions); and as the increase in the share of ETFs in the total net assets of investment funds, the main concept in the diffusion and substitution framework.

5.1. ETF markets in Japan and South Korea – preliminary evidence

As stated in the previous section, to analyse the process of diffusion of financial innovations we use monthly data on ETFs, open-end funds and closed-end funds which were available in Japan and South Korea between the years 2004 and 2017.

The two countries analysed are part of the Asia-Pacific region, which remains a rather small part of the global ETF market – as of the end of September 2017 its share was ca. 9.1% in terms of assets (Deutsche Bank, 2017). The Japanese ETF market is the largest in the region in terms of assets (ca. 61% of the whole region) and one of the leading ones in terms of turnover (a share of ca. 15%; the turnover on combined Chinese stock markets was much higher as they accounted for ca. 71% of transactions) (Deutsche Bank, 2017). The South Korean market is the third largest in both rankings yet its share in the overall Asia-Pacific region was much lower (6.5% of AUM, 11% of turnover (Deutsche Bank, 2017)), which can be explained by the smaller size of the South Korean economy in comparison to Japanese and Chinese.

First ETF in Japan was launched in 1995 (it was first innovative fund launched outside North America). However, for the remaining years of the 1990s it was the only fund listed in Japan – actual development of this market started with the introduction of next ETFs since 2001 onwards (Seki, 2007). In South Korea first innovative funds were introduced in 2002 (Samsung Asset Management 2010).

As in most other countries, the leading investment funds category in the whole time period considered was open-end funds, both in terms of total net assets and the share in the total market – in Japan their maximum share exceeded 94% in August 2010, and in South Korea 98% in May 2006. The exact market shares of closed-end funds differed but in both countries they were less popular than ETFs and open-end funds over the whole period.

In the first years of the analysed period the sizes of both ETF markets were rather low. In South Korea the minimum value of total net assets was ca. $431 million in September 2004, i.e. near the beginning of the time period analysed. The lowest value of total net assets of ETFs in Japan was observed a few years later, during the global financial crisis, i.e. in September 2009, when it amounted to ca. $23 billion (see Table 2 and Figs. 3 and 4).

The period of fast ETF market development began in South Korea sooner than in Japan: in South Korea in the second half of 2009 and in Japan at the end of 2012 and the beginning of 2013 (compare Figs. 3 and 4; see the discussion in Section 5.2.), which means that the adoption of these innovative funds occurred faster in the economy with relatively much shorter history of their usage. The quick growth of the South Korean ETF market is also proven by turnover data – between 2011 and 2013 the turnover in ETF shares on the South Korean stock exchange was the highest among all Asia-Pacific countries, even though the values of assets (or fund flows) lagged behind Japan and China. However, since 2014 South Korean market seems to have reached barriers which slowed down the expansion, such as a lack of cross-listed ETFs. Overall, the position of ETFs among the spectrum of comparable investment funds was significantly stronger in Japan: in 2004–2017 the mean total net assets in Japan were $62.3 billion versus $8.7 billion in South Korea; in terms of market share, Japan exceeded South Korea by ca. 4.8 pp. (10% versus 5.2%).

The highest values of total net assets of ETFs in both Japan and South Korea were reached at the end of analysed period, in August 2017. However, these results should be interpreted carefully as at those points in time the whole investment funds market reached its record high level in both countries (in South Korea it took place in July 2017).

Table 2
Summary statistics on exchange-traded funds, closed-end funds, open-end funds, and total investment funds. Japan and South Korea. Monthly data for January 2004–August 2017.
Source: Authors` calculations.

	Japan				South Korea			
	ETFs	Closed-end funds	Open-end funds	Total investment funds	ETFs	Closed-end funds	Open-end funds	Total investment funds
Total net assets (million USD)								
# obs.	164	164	164	164	164	164	164	164
Min	23,243.2 (2009 m2)	2424.1 (2004 m5)	179,519 (2004 m1)	213,275.9 (2004 m2)	430.9 (2004 m9)	0.0006 (2004 m1)	12,206.6 (2004 m1)	12,722.1 (2004 m1)
Max	235,810 (2017 m8)	9374.5 (2017 m10)	697,782.4 (2017 m8)	939,474.8 (2017 m8)	25,741.2 (2017 m8)	1543.5 (2017 m8)	277,316.1 (2017 m7)	304,034.3 (2017 m7)
Std dev.	51,996.8	1044.2	153,622.4	189,189.7	7836.2	298.7	70,886.5	78,334.4
Mean	62,288.5	5720.4	510,354.4	578,362.9	8654.9	418.5	123,533.5	132,606.9
Absolute change in value	207,673.4	−80.4	518,263.4	725,856.4	25,225.7	1534.3	258,081	284,841
Average monthly dynamic	1.01	0.99	1.008	1.009	1.02	1.09	1.02	1.02
Share in total net assets of investment funds [%]								
# obs.	164	164	164	–	164	164	164	–
Min	4.32 (2010 m8)	0.54 (2016 m10)	74.27 (2017 m8)	–	1.38 (2008 m3)	0.0006 (2004 m2)	88.9 (2013 m12)	–
Max	25.01 (2017 m8)	2.79 (2004 m1)	94.79 (2010 m8)	–	10.76 (2013 m12)	0.69 (2017 m7)	98.58 (2006 m5)	–
Std dev.	5.15	0.59	5.07	–	3.02	0.16	3.08	–
Mean	9.99	1.15	88.8	–	5.21	0.27	94.51	–
Absolute change in share (pp)	11.93	−2.17	−9.76	–	4.60	0.52	−5.11	–

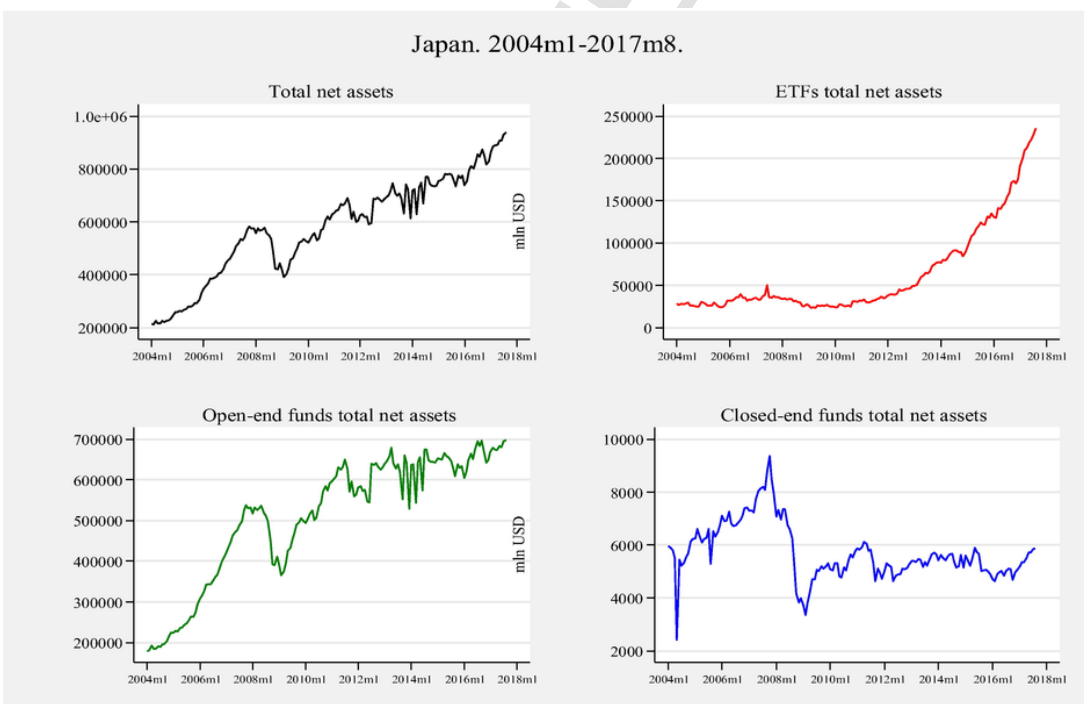

Fig. 3. Investment funds, ETFs, open-end funds and closed-end funds diffusion patterns in Japan (million USD). Monthly data for January 2004–August 2017. Source: Authors` elaboration in STATA software.

More meaningful analysis is possible by considering the shares of ETFs – in both countries the ETF markets reached the highest levels of their development in the final years of the 2004–2017 time period (in Japan in August 2017, and in South Korea sooner, in December 2013), which indicates growing popularity and diffusion – this process is analysed in detail in the next section. One notable conclusion from the results presented in Table 2 is that ETFs were the only category of funds whose market share grew in 2004–2017; the shares of both open-end funds and closed-end funds declined (with the exception of closed-end funds in South Korea but their share was highly variable and very low).

As of September 2017, in Japan the ETF market consisted mostly of equity ETFs (a 99% share in terms of assets), whereas in South Korea their share, while still the highest, was lower and amounted to ca. 78%, followed by fixed-income ETFs (Deutsche Bank, 2017). The largest ETFs in South Korea were funds tracking the main index of the Korean exchange, KOSPI 200, and the situation was similar in Japan.

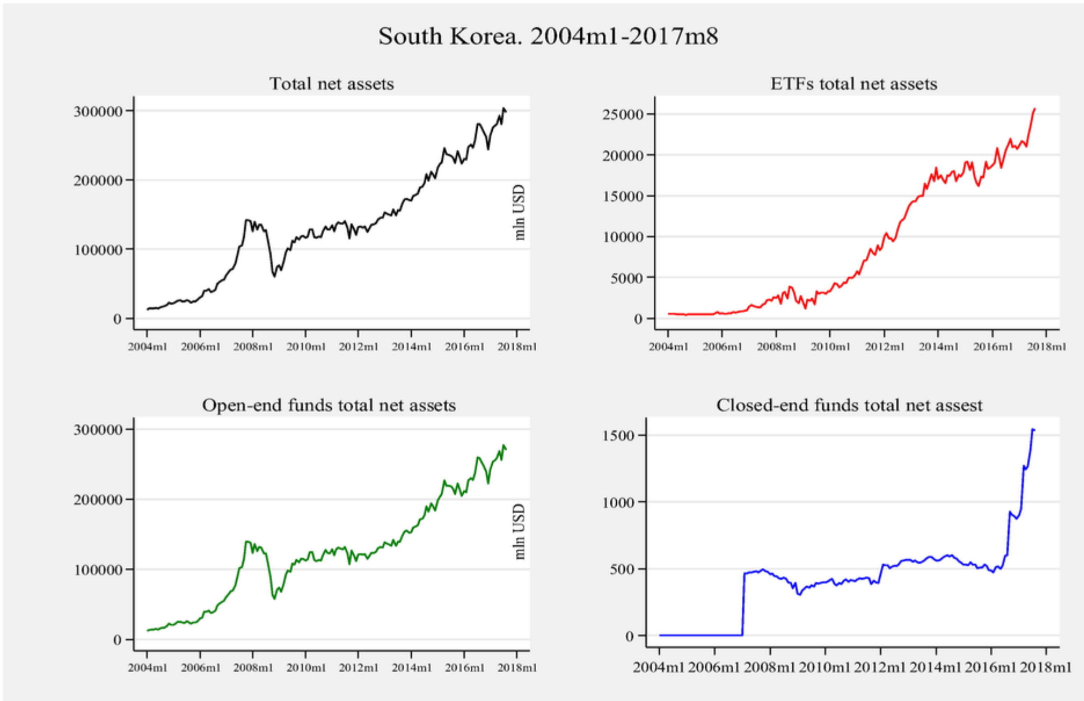

Fig. 4. Investment funds, ETFs, open-end funds and closed-end funds diffusion patterns in South Korea (million USD). Monthly data for January 2004–August 2017. Source: Authors' elaboration in STATA software.

The South Korean ETF market seems to have been more diversified in terms of the number of ETFs (after 2011 it was the highest among all the Asia-Pacific countries), with many types of ETFs available.

Almost since the inception of the first ETFs in South Korea, the main group of market participants investing in ETFs were institutional investors (such as asset management companies, banks and brokers) – this market structure is common during the initial stages of ETF market development; large financial companies are usually the first adopters of innovative financial products as they are involved in their creation and distribution (see the outline of the key features of ETFs in Section 2.1). In both countries the share of individual investors started to increase sharply during the stage of rapid ETF market development. For example, in Japan after 2013 individual investors became the second most active category (in terms of turnover) behind foreign investors; in 2015 their market share was ca. 40% (compared to foreign investors – ca. 50%, and institutional domestic investors – only ca. 10% (Tokyo Stock Exchange, 2016)).

One of the key factors which influenced the rapid development of the ETF market in both Japan and South Korea (by increasing the total net assets of innovative investment funds) was the launch of complicated ETFs offering modified returns – leveraged and short ETFs (Hill et al., 2015). In early 2012 there were no such ETFs listed on either the Japanese or South Korean stock exchanges (Johnson et al., 2012; Urakabe, 2014) but in a few years their popularity grew considerably (Deutsche Bank, 2015). Leveraged and short ETFs are subcategories of synthetic ETFs – i.e. they are based on derivatives – and are also popular in the USA (apart from the two types mentioned above, synthetic ETFs are used more often in Europe). The popularity of such funds in Japan is so high that some ETFs have grown too big, hindering proper management (e.g. in October 2015 the provider of the leveraged Nikkei 225 ETF decided not to accept any new investors (Nakamura and Sano 2015)). Leveraged and short funds contributed significantly to the diffusion of ETFs, as since 2015 in both countries they accounted for the majority of the turnover value of these funds, even though their share in the total net assets of all ETFs was between 5 and 20% (Deutsche Bank, 2015). These two complicated types of ETFs offer new advantages of ETFs versus open-end funds and closed-end funds – greater ability to use leverage or short sales which is significantly constrained in the traditional funds (the number of such funds is very low). From the perspective of the stability of the financial system this may lead, however, to the emergence of possible threats for the Japanese and South Korean financial systems. Discussion of this issue is continued in Section 5.4.

The rapid development of the Japanese ETF markets since 2013 and the linked falling shares of competing investment funds can also be attributed to various country-specific events (Deutsche Bank, 2015):

- the growing diversity of the ETF category (more types of ETFs, tracking different assets);
- introduction of ETFs tracking the newly-launched Nikkei 400 Index in January 2014 – such funds quickly gathered sizeable assets;
- purchases of ETF units by the Japanese central bank (Bank of Japan) undertaken in order to increase risk-taking activities in the economy and liquidity in the ETF market (Nakamura and Sano, 2016). The Bank of Japan ETF programme began in 2010 but with no significant effects. It was expanded in early 2013 and in autumn 2014, in both cases leading to sizeable increases in total net assets of ETFs (see Fig. 3) which were caused not only by the purchases by the Bank of Japan but also by growing investor confidence triggered by these decisions.

There are still, however, some factors hindering the development of the Japanese ETF market, such as a lack of incentives to Japanese banks to sell such products (due to the possibility of higher profits being gained from the distribution of mutual funds) and the conservatism of these institutions (PwC 2015); in South Korea, this problem is less severe because there are alternative distribution channels, e.g. fund supermarkets.

The fast development of the South Korean ETF market and the diffusion of these innovative funds observed between 2009 and 2014 were followed by a slowdown, which may be explained by saturation of the local financial markets with these products (see the discussion of diffusion model estimations in Section 5.2). However, in autumn 2015 the South Korean financial authorities and Korea Exchange announced a plan to further boost ETF market development by implementing measures such as liberalization of the ETF listing procedures, cross-listing of ETFs, and encouraging institutional investors to purchase such products (e.g. by raising investment limits) (Deutsche Bank, 2015). As a result, a new phase of fast growth began.

5.2. Financial innovation diffusion patterns

In the forthcoming sections we demonstrate and extensively discuss the results of our empirical analysis, aiming to examine the process of diffusion of investment funds and trace the emergence of financial substitution processes. We concentrate on the Japanese and South Korean financial systems in the period between 2004 and 2017. We also consider the ETF share in the total net assets of investment funds – *ETF_t^{i}_share_IF*; the open-end funds share in the total net assets of investment funds – *$Open_t^{i}$_share_IF*; and the closed-end funds share in the total net assets of investment funds – *$Closed_t^{i}$_share_IF*.

To shed light on the development patterns and the dynamics of the process of diffusion of financial innovation in the Japanese and South Korean financial systems, we use a logistic growth model to demonstrate the time evolution of the selected variables. As clarified in Section 3, adoption of a logistic growth model allows the continuous evolvement of the time path (trajectory) of a given variable to be visualized (Meyer et al., 1999; Kwasnicki 2013), and, relying on "natural growth logic" (Darwin 1986), allows the characteristic growth phases of this variable to be distinguished. Regarding the latter, Kucharavy and De Guio, 2011 also claim that the use of logistic growth models generates relatively good forecasts of the future development of the variable examined.

In our case, the logistic growth model is used to model the diffusion trajectory of innovative financial products – exchange-traded funds – in the two countries analysed during the period 2004–2017. With this aim, we run country-specific analyses and measure the value of the ETF share in the total net assets of investment funds. Henceforth, for Japan we define this as *ETF_t^{Jap}_share_IF*; and for South Korea *ETF_t^{Kor}_share_IF*.

Figs. 5 and 6 (see below), graphically present the ETF diffusion trajectories in Japan and South Korea over the period 2004–2017. Table 3 summarizes the results of the logistic growth model estimates run separately for Japan and South Korea, and Table 4 presents the predictions of future country-specific ETF diffusion patterns.

Figs. 5 and 6 provide graphical evidence of the ETF shares in the total net assets of investment funds – *ETF_t^{Jap}_share_IF* and *ETF_t^{Kor}_share_IF* – and their diffusion patterns in the Japanese and South Korean financial systems.

In Figs. 5 and 6, two characteristic phases in the diffusion patterns may easily be distinguished for Japan. First, from 2004 onwards we observe a gradual decrease from ca. 13% to less than 5% which shows a weakening position of ETFs, caused by stagnation in the value of their total net assets accompanied by rapid growth of open-end funds (compare Fig. 3). This initial stage of ETFs development is reported until August 2010 (approx. 7 years), when ETFs share reaches the lowest point (see also Table 2 to compare). Next, over the period between August 2010 and September 2012 the path showing changes in the ETFs share is unstable, demonstrating a few ups and downs; but since September 2012 an abrupt shift in the ETF share in the total net assets of investment funds is easily observed. Hence we may claim that in Japan, September 2012 has been critical turning point with respect to

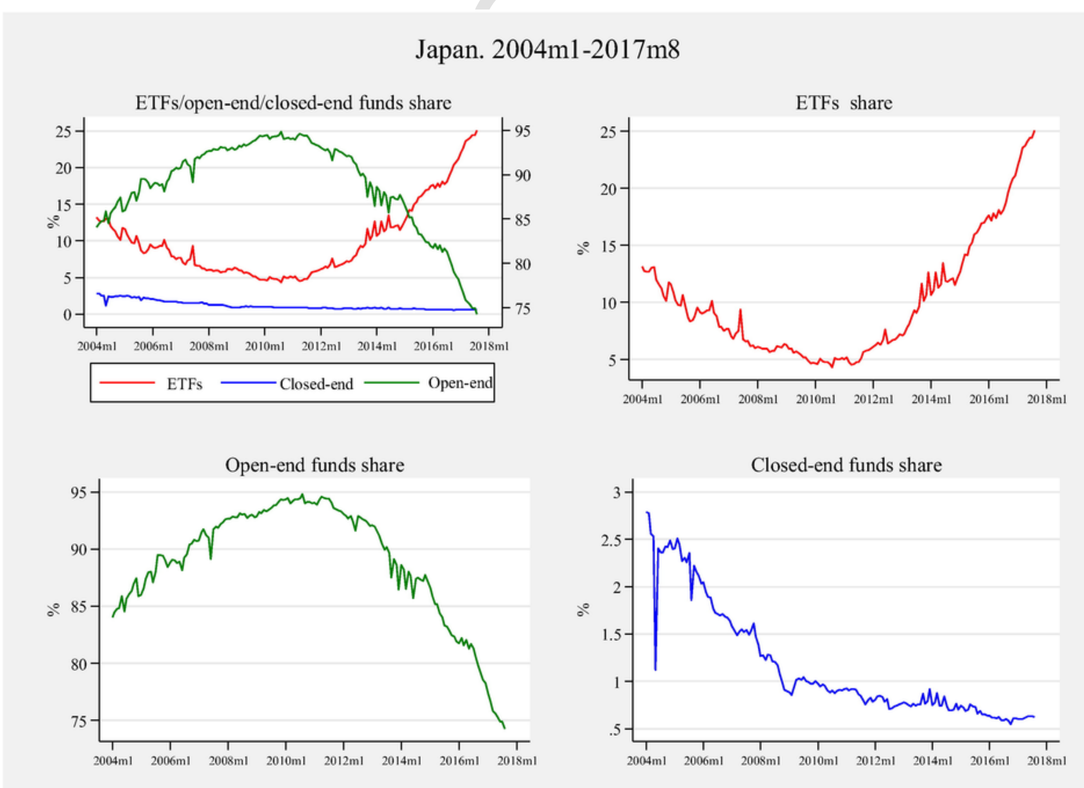

Fig. 5. Exchange-traded funds, open-end funds and closed-end funds diffusion patterns in Japan. Monthly data for January 2004 – August 2017. Share in total net assets of investment funds [%]. Source: Authors' elaboration in STATA software. Note: on left-up graph – on left axis shares of ETFs and closed-end funds, on right axis shares of open-end funds; the graphs present the empirical diffusion patterns – for the theoretical ETF diffusion patterns, see Appendix A.

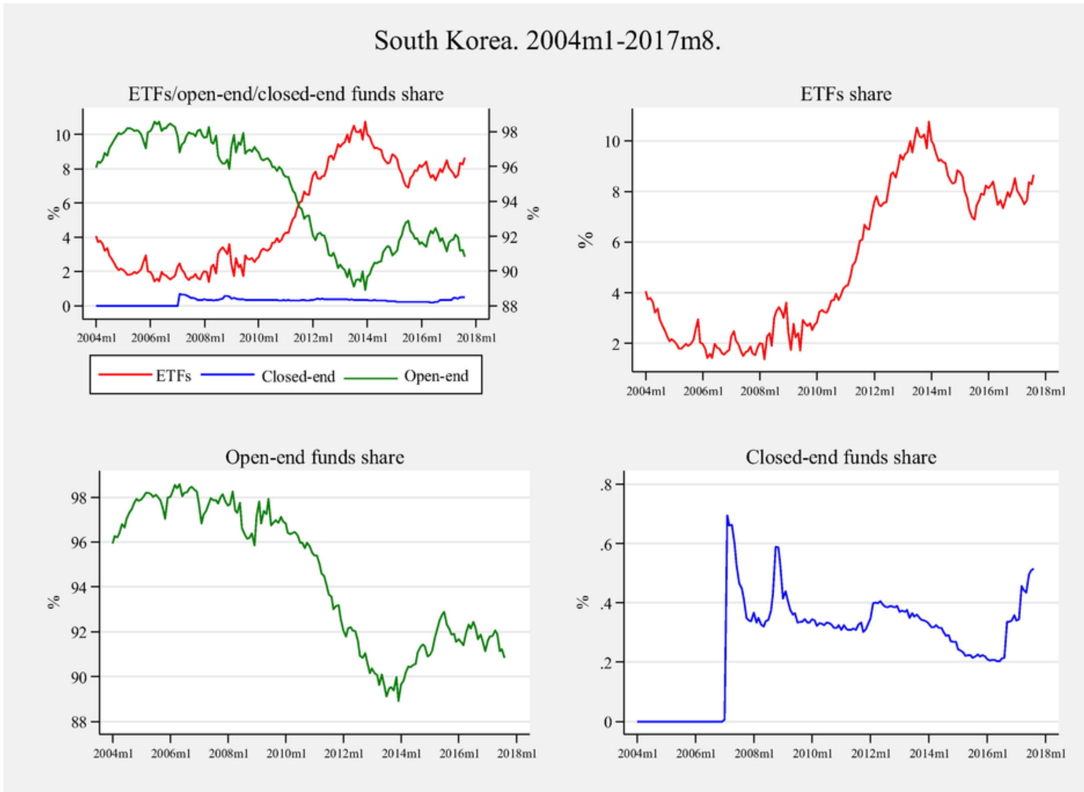

Fig. 6. Exchange-traded funds, open-end funds and closed-end funds diffusion patterns in South Korea. Monthly data for January 2004 – August 2017. Share in total net assets of investment funds [%]. Source: Authors' elaboration in STATA software. Note: on left-up graph – on left axis shares of ETFs and closed-end funds, on right axis shares of open-end funds; the graphs present the empirical diffusion patterns – for the theoretical ETF diffusion patterns, see Appendix A.

Table 3
Share of exchange traded funds in the total net assets of investment funds. Logistic growth estimates.
Source: Authors' estimates.

	Logistic growth model estimations	
	Japan	South Korea
κ_i^{ETF}(ceiling/upper asymptote)	*44,762,003.3*	9.30
Tm_i^{ETF} (β_i^{ETF}) (midpoint)	*1690*	75 (2013m3)
α_i^{ETF} (rate of diffusion)	*0.01*	0.04
Δt_i^{ETF} (specific duration)	*457*	108 (number of months)
R^2 of the model	*0.49*	0.82
# of obs.	164	164

Estimates completed using IIASA software. Misspecifications (over-estimates) in italics; the number reported for the midpoint estimates refers to specific date – we assume that number 1 is January 2004, and consecutively numbered 164 is August 2017. This applies also to the remaining estimates.

ETFs share in total net assets of investment funds. Before September 2012 the ETFs share was falling and the development path was marked by several abrupt ups and downs, but since September 2012 onward the role of ETFs was steadily growing.

Note that $ETF_{2004m1}{}^{Jap}\_share\_IF = 13.2\%$ and $ETF_{2010m8}{}^{Jap}\_share\_IF = 4.3\%$, which means a drop in ETFs share at about 67%. However, next since September 2012 ETFs share pattern in Japan takes off, which proves the increasing role of ETFs in the Japanese financial system. We see that during consecutive 12 months (between September 2012 and September 2013) the ETFs share grew by 74%; while between August 2010 and August 2017 the ETFs share increased by around 480% - from $ETF_{2010m8}{}^{Jap}\_share\_IF = 4.3\%$ up to $ETF_{2017m8}{}^{Jap}\_share\_IF = 25.1\%$.

On the Japanese stock exchange, the period between August 2010 and September 2012 is critical, as during these 13 months the ETF diffusion pattern, after almost 5-year period of diminishing ETFs share, finally leaves the initial growth phase and enters the exponential growth phase. From September 2012 onwards, the ETF share in the total net assets of investment funds in Japan is steadily growing, reaching its peak in September 2017 when $ETF_{2017m8}{}^{Jap}\_share\_IF = 25.1\%$. Trying to establish whether ETFs share development pattern in Japan resembles in-shape the sigmoid trajectory (see Fig.1), we may claim that only two phases – early and exponential growth stages, may be distinguished. Between January 2004 and August 2010 we observer the early diffusion phase during which the ETFs share remains relatively low although multiple ups and downs are observed; and next – the second stage since September 2010 onward when rapid shifts in ETFs share in Japanese financial system are demonstrated.

In case of South Korea, the diffusion pattern of ETFs starts with a kind of "plateau", where, at the beginning of the period analysed, from January 2004 until November 2010, $ETF_{2004m1-2010m11}{}^{Kor}\_shareIF$ is below 4%. Obviously, during this initial period of ETFs development in South Korea we observe random ups and downs but the average ETFs share is around 2.4% thus we may argue that the relative role of ETFs in South Korean financial system remained low between January 2004 and November 2010.

However, since November 2010 onward an abrupt shift in the ETF share in the total net assets of investment funds took place and specific take-off is reported. This period between December 2010 and December 2013 is clearly critical as it shows radical changes in the level of ETFs share in South Korean financial system. Notably, we have observed leaving the early development phase and entering stable growth pattern as since November 2010 the ETFs share has been systematically increasing. We observe that $ETF_{2010m11}{}^{Kor}\_share\_IF = 3.8$ but $ETF_{2011m9}{}^{Kor}\_share\_IF = 6.7\%$, which means growth of almost 72% during 11 months. Next, between September 2011 and December 2013 the

Table 4
Predicted share of exchange traded funds in the total net assets of investment funds development scenarios. Japan and South Korea.
Source: Authors' estimates.

κ_i^{ETF} (upper asymptote) –*fixed*	Tm_i^{ETF} (midpoint)	Δt_i^{ETF} (specific duration) – number of months	α_i^{ETF} (rate of diffusion)	R^2
Japan				
15%	*Achieved*			
20%	*Achieved*			
25%	*Achieved*			
30%	149 (May 2016)	369 (approx. 31 years)	0.01	0.38
35%	170 (Feb 2018)	379 (approx. 31 years)	0.01	0.40
40%	189 (Sept 2019)	387 (approx. 32 years)	0.01	0.42
45%	205 (Jan 2021)	393 (approx. 33 years)	0.01	0.43
50%	219 (Mar 2022)	399 (approx. 33 years)	0.01	0.44
South Korea				
15%	122 (Feb 2014)	241 (approx. 20 years)	0.02	0.75
20%	159 (Mar 2017)	296 (approx. 25 years)	0.02	0.73
25%	189 (Sept 2019)	328 (approx. 27 years)	0.01	0.72
30%	214 (Oct 2021)	349 (approx. 29 years)	0.01	0.72
35%	235 (July 2023)	364 (approx. 30 years)	0.01	0.71
40%	253 (Feb 2024)	376 (approx. 31 years)	0.01	0.71
45%	269 (May 2026)	385 (approx. 32 years)	0.01	0.71
50%	282 (June 2027)	392 (approx. 33 years)	0.01	0.70

ETFs share rose by almost 62%, reaching its peak in December 2013 – $ETF_{2013m12}^{Kor}$*_share_IF* = 10.7%. Another interesting observations is that after achieving the peak point in December 2013, the ETFs share started to fall slightly so that in July 2015 in reached ETF_{2015m7}^{Kor}*_share_IF* = 6.8%; however, during consecutive months we observe random shifts and falls with this respect. Notably, the in-time changes in ETFs share in South Korea between January 2004 and August 2017 allow distinguishing 3 unique phases of growth that are characteristic for the S-shaped time path generated by logistic growth (see Eq. 6 for instance). We can visibly distinguish the initial (early) phase of growth between January 2004 and November 2010, next the phase of rapid growth between December 2010 and December 2013, and finally the stabilization phase between January 2014 and August 2017.

The graphical evidence presented in Figs. 5 and 6 suggests that these ETF diffusion patterns in Japan and South Korea are relatively well described by the logistic (sigmoid) growth trajectory and the characteristic phases of the S-shaped path can be distinguished (particularly in the second country). Initial declines or slow changes in the share of ETFs are followed by a sudden take-off and then the pattern enters the phase of rapid growth. Possible causes of this accelerated growth were discussed in Section 5.1, of which the launch and increasing popularity of leveraged and synthetic ETFs seems the most probable.

We now use the logistic growth model to estimate the specific parameters characterizing the processes of ETF diffusion in the countries under study. The estimation results of the logistic growth models – see Eqs. 9 and 10 – are summarized in Table 3. As this table shows, in the case of Japan the parameter estimated for the upper asymptote (growth limit) is $\kappa_{Jap}^{ETF} = 44{,}762{,}003$, which indicates an obvious misspecification. Similar misspecifications are returned in the case of the other parameters, namely β_{Jap}^{ETF}, α_{Jap}^{ETF} and Δt_{Jap}^{ETF}. During more than a half of the time period examined, Japan was still in the early exponential growth phase and this leads to unreliable estimates, especially regarding the upper asymptote (growth limit) – κ_{Jap}^{ETF}.

For South Korea, all the estimated logistic growth model parameters turn out to be statistically significant. Moreover, the R^2 of the model is about 0.82, which suggests a very good fit of the empirical data to the theoretical model. The ceiling (upper asymptote) is estimated as $\kappa_{Kor}^{ETF} = 9.30\%$, and this parameter indicates the potential (maximum) level of the ETF share in the total net assets of investment funds, based, however, on the rigid assumption that the ETF diffusion pattern follows the theoretical trajectory generated by the logistic growth model. The estimated midpoint is $Tm_{Kor}^{ETF} = 75$ and this represents the exact time when ETF_t^{Kor}*_share_IF* reached 0.5κ. The estimated $Tm_{Kor}^{ETF} = 75$ suggests that the midpoint was reached in exactly March 2013 (see also the figures in Appendix A). Next, the rate (speed) of diffusion is $\alpha_{Kor}^{ETF} = 0.04$. However, as this parameter has no direct economic interpretation we use it to calculate the "specific duration." As $\alpha_{Kor}^{ETF} = 0.04$, $\Delta t_{Kor}^{ETF} = 108$, which may be interpreted as the number of months needed to pass from 10% to 90% of κ_{Kor}^{ETF}.

To evaluate the future prospects of ETF development, we estimate hypothetical scenarios of future ETF_t^i*_share_IF* diffusion both in Japan and South Korea (see Appendix A for graphical representations). Fixing the critical level of the upper asymptote (κ_i^{ETF}) at 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50%, we forecast respective logistic growth model parameters, always under the rigid assumption that ETF_t^i*_share_IF* in the country analysed will follow the S-shaped trajectory.

The results of the forecasts are summarized in Table 4. The first scenario, for Japan, forecasts the ETF_t^{Jap}*_share_IF* diffusion trajectory with the ceiling κ_{Jap}^{ETF} set at 15%, and in the following ones we increase it by 5 p.p.; however as indicated in Table 4, the κ_{Jap}^{ETF} set at 15%, 20% and 25% have already been reached by August 2017, and thus are excluded from the analysis. For each consecutive scenario – 30%, 35%, 40%, 45% and 50%, we predict the midpoint – Tm_{Jap}^{ETF}– and the 'specific duration – Δt_i^{ETF} in order to assess how much time (in months) would be needed to pass from 10% to 90% of the given fixed κ_{Jap}^{ETF}. It should be remembered that the estimates of the logistic growth model for Japan turned out to be statistically insignificant and heavily biased due to the fact that during the period analysed Japan was still in the early exponential growth phase along the S-shaped diffusion path.

For South Korea we forecast the ETF_t^{Kor}*_share_IF* diffusion trajectory with the ceiling κ_{Kor}^{ETF} set at 15%, and in the following ones we increase it by 5 p.p, up to 50%. For all scenarios the R-square of the model is between 0.70 and 0.75 thus these forecasts may be treated as valid and reliable. The estimated rate of growth α_{Kor}^{ETF} is 0.02 for $\kappa_{Kor}^{ETF}=15\%$ and $\kappa_{Kor}^{ETF}=$ 20%, while for the remaining ones α_{Kor}^{ETF} is 0.01. Considering the forecasts for $\kappa_{Kor}^{ETF}=15\%$, the estimated midpoint Tm_{Kor}^{ETF} is February 2014 and the "specific duration" for about 20 years. As for $\kappa_{Kor}^{ETF} = 20\%$, the estimates are for Tm_{Kor}^{ETF} in March 2017 and "specific duration" for about 25 years. Of course these forecasts are only true if assuming that during the next periods the dynamics of ETFs share growth will be maintained.

The results for Japan and South Korea for $\kappa_i^{ETF}$for 30%, 35%, 40%, 45% and 50% are similar in terms of predicted rate of diffusion which in each case is $\alpha_i^{ETF} = 0.01$. "Specific durations" are also very similar and range from about 29 years in South Korea for $\kappa_{Kor}^{ETF}=30\%$, to about 33 years in South Korea for $\kappa_{Kor}^{ETF}=45\%$ and $\kappa_{Kor}^{ETF}=50\%$ (also in Japan for $\kappa_{Jap}^{ETF}=50\%$). By definition the forecasted "specific duration" is directly associated with the rate of growth – α_i^{ETF}, which in here results to be analogous for each forecast. However, in terms of forecast midpoints – Tm_i^{ETF}, there are differnces between Japan and South Korea. For Japan the estimated midpoints vary from May 2016 (for $\kappa_{Jap}{}^{ETF} = 30\%$) until March 2022 (for $\kappa_{Jap}{}^{ETF} = 50\%$); while for South Korea – between October 2021 and June 2027 for analogous κ_i^{ETF}. In case of Japan the predicted midpoints for consecutive ceilings are about to happen faster compared to South Korea, as in August 2017 (the end period of analysis) Japan was still located in the fast growth phase regarding changing ETFs share. In contrast, in South Korea the ETFs diffusion path has already entered the stabilization phase, showing significant slowdown in the process of ETFs share growth, which in turn considerably affected the forecasts.

Finally, it must be underlined that all these forecasts are uncertain and should be treated with caution. The predicted future diffusion paths are not purely random but instead follow the S-shaped trajectory and they all have high sensitivity to historical data. Special attention should be paid to predictions referring to relatively high fixed ceilings, like for instance 45% or 50%, where the accuracy of the forecast may be questionable and, to some extent, misleading and inconclusive.

5.3. Equity ETFs-open end funds financial substitution

This section presents a detailed analysis of the emerging process of financial substitution which can be traced in both countries analysed between 2004 and 2017. As preliminary evidence, in Table 5 we present the changing market shares of ETFs, open-end funds and closed-end funds. Interestingly, in the cases of both Japan and South Korea we observe a rapid expansion of ETFs during the period examined – this category of investment funds was gradually increasing its market shares. In Japan, the absolute change in market share between December 2004 and August 2017 was 13.5 pp., while in South Korea the change is 6.5 pp. In both countries, the growth of this financial innovation parallels a decline of open-end funds. At the same time, despite several observed changes, the market share of closed-end funds in the total market for investment funds remained very low in South Korea; in Japan it has been declining. Hence, a preliminary conclusion may be drawn that in Japan and South Korea ETFs are gradually gaining in market share at the expense of a decreasing role for both open-end and closed-end funds.

Comparison of market shares of ETFs and closed-end funds in Table 6 (regarded together as alternatives to leading open-end funds) shows clearly that as early as in 2004–2007 the share of ETFs was much higher. Over the next years it has increased even further, reaching ca. 98% of the total market for these two categories in Japan and ca. 95% in South Korea. As a result, market shares of ETFs versus closed-end funds should not be analysed using substitution framework as there was no observed or even predicted "switching" from one type of investment funds to another (i.e. one of the categories approaching or exceeding 50% market share).

We will, therefore, focus on substitution between ETFs and open-end funds in one subcategory – equity funds. There are two main reasons for such choice. First, equity ETFs are the oldest and largest category of the innovative investment funds in both countries. Second, Table 5 demonstrates that in both Japan and South Korea between 2004 and 2017 a huge part of the investment funds markets belonged to open-end funds which means that they (not rather marginal closed-end funds) may be considered main competitors for ETFs. Bearing this in mind, we argue that the process and patterns of financial substitution should be analysed mostly between ETFs and open-end funds based on equities (i.e. equity ETFs and open-end funds), which we label below as "Equity Investment Funds"; closed-end funds have already lost almost entire market share to other funds (additionally, equity closed-end funds are rare in the analysed countries).

With this aim, we assume that equity ETFs and open-end funds constitute a separate hypothetical market, and the process of financial substitution is limited to gradually changing market shares between the two types of investment funds. Put differently, we assume that ETFs as financial innovations are invading the financial systems and this generates competition between equity ETFs and open-end funds, eventually leading to increases in the market shares of ETFs. We also define*$ETFs^{Jap}$_share_EQ*, *$ETFs^{Kor}$_share_EQ* showing share of ETFs funds share in total hypothetical market – Equity Investment Funds market – defined as above, for Japan and South Korea accordingly; and analogously *$Open^{Jap}$_share_EQ* and *$Open^{Kor}$_share_EQ* for open-end funds.

Table 7 shows market shares of equity ETFs and open-end funds in the total net assets of equity investment funds in Japan and South Korea over the period 2004–2017. It shows that in South Korea initially in December 2004 the ETFs share was *$ETFs^{Kor}$_share_EQ* = 17.6%, but then during next 8 years (between 2004 and 2011) its share has radically fallen, reaching the low-point in December 2007 when it dropped until 2.4%. However since December 2012 onwards the level of *$ETFs^{Jap}$_share_EQ*steadily increased, reaching *$ETFs^{Kor}$_share_EQ* = 25.5% in August 2017. During the period December 2007 and August 2017 the ETFs share in Equity Investment Funds market shifted by approximately 962%, hence ETFs share growth was pervasive, which was becoming at the expense of open–end funds.

Table 5
Changes in investment funds market shares in Japan and South Korea. January 2004–August 2017.
Source: Authors' elaboration.

	Japan			South Korea		
	ETFs [%]	Open-end funds [%]	Closed-end funds [%]	ETFs [%]	Open-end funds [%]	Closed-end funds [%]
2004m12	**11.7**	**85.9**	**2.4**	**2.2**	**97.8**	**0.00000344**
2005m12	9.5	88.4	2.1	2.1	97.8	0.00000278
2006m12	7.7	90.7	1.6	1.8	98.2	0.00000144
2007m12	5.9	92.7	1.4	1.9	97.8	0.3
2008m12	6.3	92.8	0.9	3.7	95.8	0.5
2009m12	4.7	94.3	1.0	2.8	96.9	0.3
2010m12	5.2	93.9	0.9	4.2	95.5	0.3
2011m12	5.9	93.3	0.8	7.1	92.6	0.3
2012m12	7.1	92.1	0.8	9.4	90.2	0.4
2013m12	12.7	86.4	0.9	10.8	88.9	0.3
2014m12	12.7	86.4	0.9	8.9	90.8	0.3
2015m12	17.5	81.9	0.6	8.3	91.5	0.2
2016m12	21.1	78.3	0.6	8.5	91.1	0.4
2017m8	**25.2**	**74.2**	**0.6**	**8.7**	**90.8**	**0.5**

Note: very low markets shares of closed-end funds in South Korea over 2004–2006 may be caused by data availability issues regarding their total net assets (information in the databases is insufficient to determine the actual values).

Table 6
Changing market shares of ETFs versus closed-end funds considered as total market. Japan and South Korea. January 2004–August 2017.
Source: Authors' calculations.

	Japan		South Korea	
	ETFs [%]	Closed-end funds [%]	ETFs [%]	Closed-end funds [%]
2004m12	**83.1**	**16.9**	**x**	**x**
2005m12	82.4	17.6	x	x
2006m12	82.4	17.6	x	x
2007m12	81.2	18.8	84.5	15.5
2008m12	87.6	12.4	87.3	12.7
2009m12	82.4	17.6	89.1	10.9
2010m12	84.8	15.2	92.8	7.2
2011m12	88.4	11.6	95.6	4.4
2012m12	90.4	9.6	96.0	4.0
2013m12	93.2	6.8	97.0	3.0
2014m12	94.6	5.4	97.1	2.9
2015m12	96.5	3.5	97.4	2.6
2016m12	97.2	2.8	96.0	4.0
2017m8	**97.6**	**2.4**	**94.4**	**5.6**

Note: values for South Korea for 2004–2006 are not included due to possible data availability issues regarding total net assets of closed-end funds (insufficient information in the Lipper database).

Table 7
Changing market shares of equity ETFs versus equity open-end funds considered as total market. Japan and South Korea. January 2004–August 2017.
Source: Authors' calculations.

	Japan		South Korea	
	Equity ETFs [%]	Equity open-end funds [%]	Equity ETFs [%]	Equity open-end funds [%]
2004m12	**36.7**	**63.3**	**17.6**	**82.4**
2005m12	27.7	72.3	8.5	91.5
2006m12	20.4	79.6	3.8	96.2
2007m12	15.8	84.2	2.4	97.6
2008m12	21.8	78.2	5.7	94.3
2009m12	14.0	86.0	3.2	96.8
2010m12	15.2	84.8	5.1	94.9
2011m12	17.3	82.7	8.1	91.9
2012m12	21.1	78.9	13.3	86.7
2013m12	25.1	74.9	18.2	81.8
2014m12	24.7	75.3	18.9	81.1
2015m12	31.5	68.5	19.7	80.3
2016m12	37.8	62.2	24.2	75.8
2017m8	**43.6**	**56.4**	**25.5**	**74.5**

Similar tendencies were observed in Japan – initially the ETFs share in the Equity Investment Funds market was falling, but then since December 2011 we observe dynamic increases of $ETFs^{Kor}$_*share_EQ*. Evidently, in both Japan and South Korea equity ETFs as financial innovations are rapidly invading the financial system at the expense of open-end funds. In South Korea, however, this change seems to be more radical, as the absolute change (in pp.) between December 2004 and August 2017 was ca. 7.9 pp., while in Japan it was 6.9 pp. Despite this, in the Japanese financial system the role of ETFs in challenging open-end funds seems to be more significant. In Japan between 2004 and 2017 the maximum of $ETFs^{Jap}$_*share_EQ* was 43.6% while the analogous value in South Korea was much lower, with $ETFs^{Kor}$_*share_EQ* reaching 25.5%; in both cases the maximum of ETFs share was observed in August 2017.

The following part of this section presents empirical evidence on the dynamics and degree of *equity ETFs to open-end funds* substitution in Japan and South Korea between 2004 and 2017. Figs. 7 and 8 show the financial substitution effects encountered in the two economies and Table 8 summarizes the results from the financial substitution models estimated for equity investment funds (ETFs and open-end funds).

Figs. 7 and 8 clearly demonstrate that the process of "switching" from one type of equity investment funds – open-end funds – to another – ETFs – can be easily traced for both countries. In both examined countries the process of financial substitution is gradual and until August 2017 has not been finished. However, if the dynamics of changing market shares between equity ETFs and equity open-end funds is maintained during consecutive periods, the financial substitution should be completed, hence ETFs share shall exceed open-end shares in the total Equity Investment Funds market. Nevertheless, in both countries ETF to open-end funds financial substitution can be seen as a "fight" between these investment funds to take over the market. In each phase of the process, the market share of the given type of investment fund is different and determined by the rate of financial substitution.

In Japan, the process of substitution, which may labelled as "*equity ETFs to open-end funds*", is revealed as very interesting. Considering complete time series analysed (January 2004–August 2017) no rigid conclusions can be drawn as the financial substitution is not definite. Additionally, the parameters (Tm_{Jap}^{δ} and Δt_{Jap}^{δ}) estimated by the financial substitution model (for theoretical specification see Section 3) are statistically insignificant. In case of Japan returned parameters are obvious misspecifications; while for South Korea they are evidently overestimated which is a consequence of unstable financial substitution patterns displayed for both examined countries. Visibly, in both cases, initially the financial substitution patterns are diverging and next start to converge. More detailed analysis of the financial substitution patterns in Japan shows that two unique phases of the process may be easily distinguished (see Fig. 7). We therefore decompose the original time series (original sample) into two sub-samples and label each sub-sample a specific "Financial Substitution Phase – FSP". This yields:

- FSP_1_Jp: covering the period from January 2004 to April 2011;
- FSP_2_Jp: covering the period from May 2011 to August 2017.

Fig. 7 plots *equity ETFs to open-end funds* financial substitution patterns for FSP_1_Jp and FSP_2_Jp and Table 8 summarizes the financial substitution model estimates for each phase separately. During FSP_1_Jp (2004 m1-2011 m4), the evidence on market competition between equity ETFs and equity open-end funds indicates that in this period ETFs may be labelled "losing" equity investment funds, as between January 2004 and April 2011 in Japan their share has dropped from 41.8% to 13.1%. Evidently, during the FSP_1_Jp period ETFs lose their winning market position, and are being gradually substituted by open-end funds. The returned parameters from the financial substitution model estimates for FSP_1_Jp are statistically insignificant (see Table 8), which is due to the fact that during this period the substitution patterns are visibly diverging instead of converging. During the next phase – FSP_2_Jp (2011 m5-2017 m8), the trajectories change sharply their direction. From May 2011 onwards equity ETFs gradually gain a growing market share while equity open-end funds lose their wining position. In this sub-period – FSP_2_Jp, the substitution patterns constantly diverge, revealing the process of equity ETF market invasion at the expense of equity open-end funds. Note that at the beginning of FSP_2_Jp the $ETFs^{Jap}$_*share_EQ* = 13.3% and $Open^{Jap}$_*share_EQ* = 86.7%, but in August 2017$ETFs^{Jap}$_*share_EQ* = 43.6% and $Open^{Jap}$_*share_EQ* = 56.4%. It may therefore arguably be stated that in mid-2017 the Equity Investment Funds market was almost equally divided between equity ETFs and open-end funds. According to the financial substitution model estimates for FSP_2_Jp period (see Table 8), Tm_{Jap}^{δ} = month 185 (May 2019) demonstrating the theoretical (modelled) time when the time when the process of financial substitution is half complete, hence

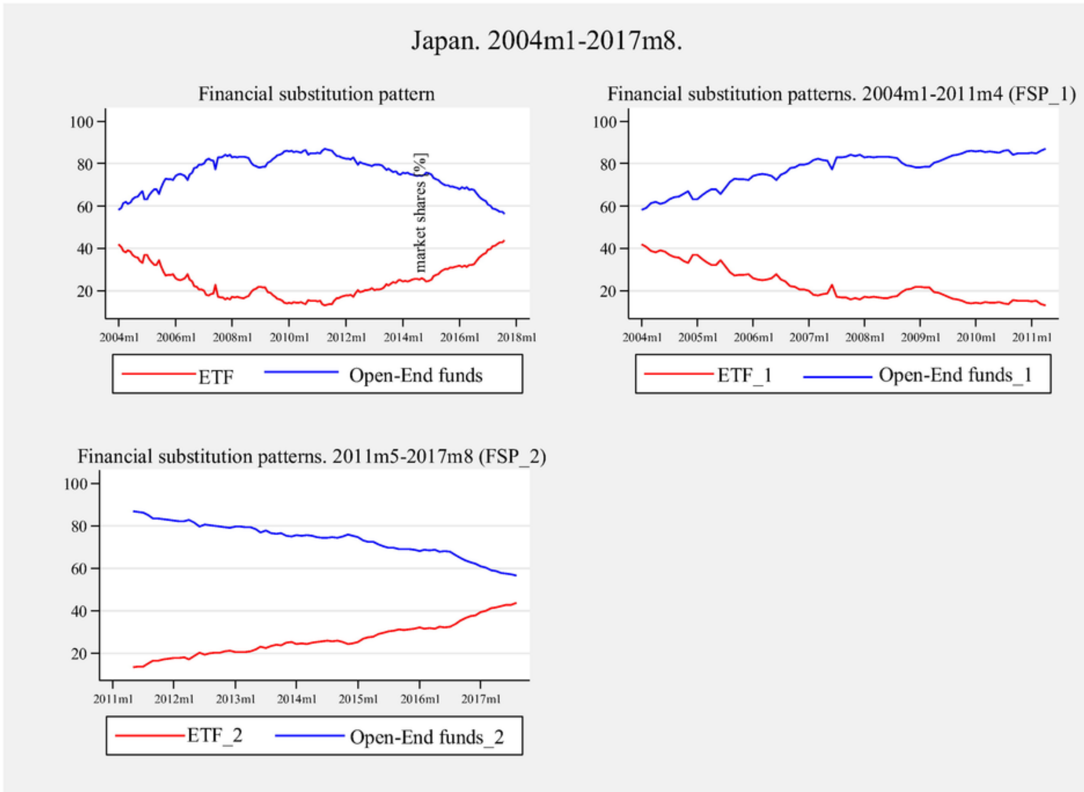

Fig. 7. Financial substitution patterns. Equity ETFs versus equity open-end funds in Japan. Monthly data for January 2004–August 2017. Source: Authors` elaboration in STATA software.

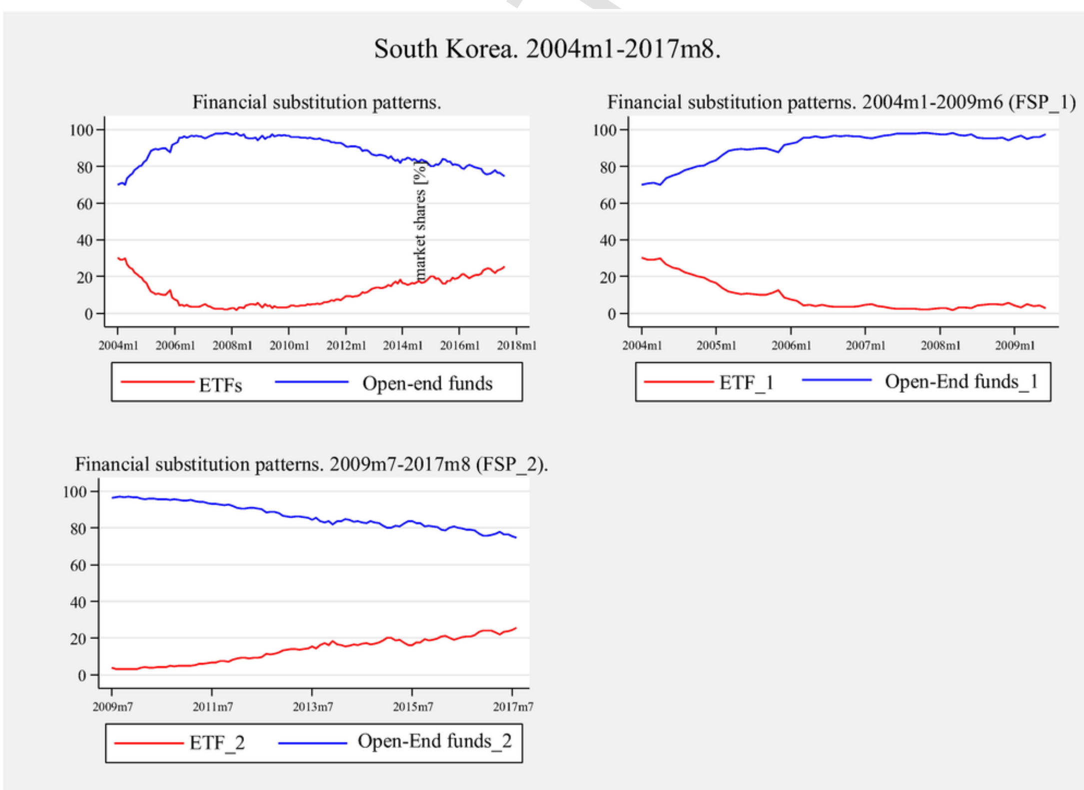

Fig. 8. Financial substitution patterns. Equity ETFs versus equity open-end funds in South Korea. Monthly data for January 2004 – August 2017. Source: Authors` elaboration in STATA software.

Table 8
Financial substitution model estimates. Japan and South Korea. January 2004–August 2017.
Source: Authors' elaboration.

	Japan		South Korea	
	Equity exchange traded funds versus equity open-end funds			
Full sample estimates				
Tm_i^δ	*957*	Substitution NOT reported. Paths initially diverging, then – converging.	359[a] (September 2033)	Substitution NOT reported. Paths initially diverging, then – converging.
Δt_i^δ	*3257*		532 (44 years and 3 months)	
Sub-samples estimates				
	2004 m1 to 2011 m4 (FSP_1_Jp)	Paths diverging	**2004 m1 to 2009 m6 (FSP_1_Kor)**	Paths diverging
Tm_i^δ	*−35*		*−33*	
Δt_i^δ	*−272*		*−109*	
	2011 m5 to 2017 m8 (FSP_2_Jp)	Paths converging – if the dynamics of the process is maintained, then the substitution shall be reported around 2018–2019	**2009 m7 to 2017 m8 (FSP_2_Kor)**	Paths converging – if the dynamics of the process is maintained, then the substitution shall be reported around 2019–2020.
Tm_i^δ	185 (May 2019)		199 (July 2020)	
Δt_i^δ	243 (20 years and 2 months) – overestimates		182 (15 years and 1 month)	

Note: misspecifications in italics; Tm_i^δ– time (year and month) when financial substitution is half complete; Δt_i^δ – takeover time (specific number of months).
[a] Potential overestimates.

$f_{Jap}^{\delta}(t) = f_{Jap}^{\theta}(t) = 0.5$, meaning that both equity ETFs and open-end funds possess equally 50% of the market. Moreover, the "take-over" time is estimated as $\Delta t_{Jap}^{\delta} = 243$ months (approx. 20 years), indicating the number of months necessary for the market share of the invading innovative financial funds (ETFs) to grow from 10% to 90% of the market share. However, we believe that in this case the returned parameter Δt_{Jap}^{δ} may be overestimated, and that this process should proceed faster.

Turning to South Korea, the substitution process is displayed visually in Fig. 8 and it is similar in type to that identified in Japan. As for Japan, two distinct phases may be traced for Korea, namely:

- FSP_1_Kor: covering the period from January 2004 to June 2009
- FSP_2_Kor: covering the period from July 2009 to August 2017.

Considering the FSP_1_Kor phase, at the beginning of the period examined, *ETFs*^{Kor}*_share_EQ* in January 2004 was at about 30.2%, but during next 12 months it fell radically so that in December 2004 *ETFs*^{Kor}*_share_EQ* = 17.6%. For the next years the ETFs share in Equity Investment Market was gradually decreasing reaching the low-point in March 2008, when *ETFs*^{Kor}*_share_EQ* = 1.9%, i.e. the role of ETFs was negligible. Then, since March 2008 onward, the equity ETFs share development pattern was marked by random ups and downs until July 2009 when the second identified phase starts – FSP_2_Kor and during consecutive period the *ETFs*^{Kor}*_share_EQ* increases. In July 2009 the equity ETFs share was 6.9% and was steadily growing until August 2017 when *ETFs*^{Kor}*_share_EQ* = 25.5%. Henceforth, arguably between July 2009 and August 2017 the equity ETFs were gaining higher marker shares while their competitive investment funds – equity open-end funds were diminishing their role on the market analysed.

Table 8 displays estimates parameters from the financial substitution model estimates both for the full sample as well as for the sub-periods (FSP_1_Kor and FSP_2_Kor). As for the FSP_1_Kor, analogously as in Japan, estimated parameters are not valid. As already noted, between January 2004 and June 2009 equity ETFs share was falling – the respective paths visualizing changing shares of equity ETFs and open-end funds were diverging. Estimated parameters for FSP_2_Kor are Tm_{Kor}^{δ} = month 199 (July 2020) and $\Delta t_{Kor}^{\delta} = 182$ months (approx. 15 years), where the Tm_{Kor}^{δ} indicates the potential time when the process of financial substitution was half complete, when $f_{Kor}^{\delta}(t) = f_{Kor}^{\theta}(t) = 0.5$, and $-\Delta t_{Kor}^{\delta} = 182$ months – the number of months needed for $f_{Kor}^{\delta}(t)$ to pass from 10% to 90%. Put differently, assuming that the dynamics of the process of equity ETFs share is maintained during next years, the ETFs shall become the dominant funds by the years 2019–2020.

Finally, we examine additional evidence considering forecast of equity ETFs and open-end funds shares until 2030. Country-wise predictions are made using complete time series, i.e. monthly data between 2004 and August 2017. Fig. 9 (below) graphically traces the process of financial substitution between equity ETFs and open-end funds in Japan and South Korea for the period examined. In the case of Japan, we observe gradually diminishing market shares of equity open-end funds, while the share of equity ETFs is increasing; however, this process is much slower compared to South Korea. Henceforth, when using full sample data, the equity ETFs to open-end funds financial substitution (i.e. equity ETFs reaching 50% market share) may not be predicted within reliable time span (the results are different when only FSP_2_Jap is considered, as discussed in the preceding paragraphs).

In South Korea, the future relations between equity ETFs and equity open-end funds may potentially be different, which is mostly due to varying dynamics of changes in the two analysed countries. These difference are especially visible within the sub-periods FSP_2_Kor and FSP_2_Jap, where in Korea the average monthly growth of the equity ETFs share was 2.3% and in Japan it was much lower (1.5%). Thus, in South Korea the process of financial substitution is relatively more dynamic, as visually reflected in Fig. 9. As a consequence of these relatively more rapid changes, according to the predictions, by the year 2030 the market share of equity open-end funds should decline to 50% and over the next years they may be projected to be substituted by ETFs. However, increases in the market share of ETFs may be slowed down due to the ETF market growth barriers (discussed in Section 5.1).

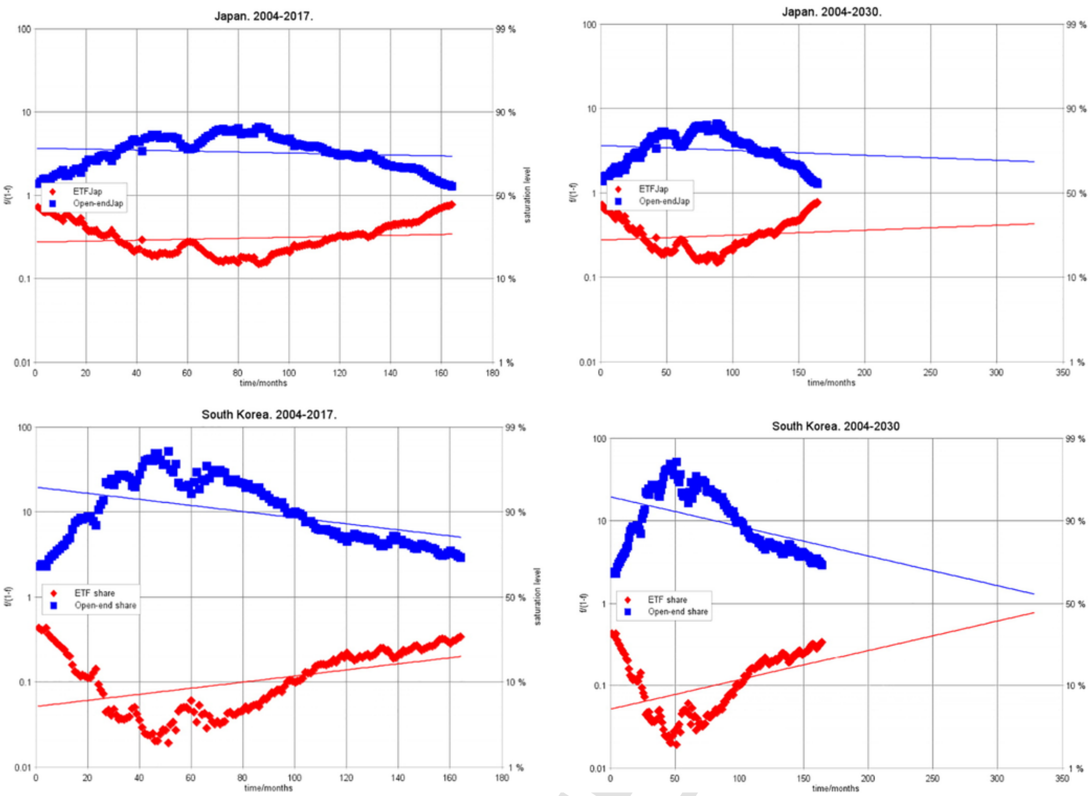

Fig. 9. Financial substitution patterns. Equity ETFs versus equity open-end funds. Japan and South Korea. January 2004 – August 2017 and predictions. Source: Authors' elaboration in IIASA software. Note: Estimated model $-\frac{\kappa_i^{\delta}}{1+\exp\left(-\alpha_i^{\delta}\left(t-\beta_i^{\delta}\right)\right)}+\frac{\kappa_i^{\theta}}{1+\exp\left(-\alpha_i^{\theta}\left(t-\beta_i^{\theta}\right)\right)}=1$, with notations as in Eq. 23. Fisher-Pry transformation applied for visualization. For Japan, Fisher-Pry Y-axis range = 0.01–100; for South Korea, Fisher-Pry Y-axis range = 0.01–100.

5.4. Exchange-traded funds in Japan and South Korea: potential impact on the financial systems

ETFs may influence the financial system through a number of transmission channels, potentially leading to the emergence of threats to financial stability as discussed in Section 2.3. However, in the case of a poorly developed ETF market the level of the risk is insignificant. In Japan and South Korea for most of the time period analysed the total net assets of ETFs were much smaller than total net assets of open-end funds. Nevertheless, in Section 5.2. critical periods were identified marking the moments of a start of rapid ETF market development and thus the beginning of a growing impact of ETFs on the local financial systems. For Japan this was August 2010–September 2012, while for South Korea it was December 2010–December 2013.

In Section 2.3 the possible negative outcomes for the financial system linked to the development of ETF markets were divided into four categories. Below we discuss the importance of these threats with reference to Japan and South Korea.

1. Liquidity risk: in the final years of the time period analysed the Japanese and South Korean ETF markets were very liquid (at least in the largest segments) as demonstrated by high turnovers in comparison to their assets. For example, according to the December 2016 data, in Japan monthly turnover amounted to ca. 21% of the total net assets and in South Korea it was even higher (ca. 61%). However, since 2016 the value of this ratio has been declining in Japan due to very quick growth of the total net assets accompanied by declining value of turnover which could signal some potential stability threats. In the earlier years, before the critical periods, the liquidity in both Japan and South Korea was much smaller but the size of the ETF markets (and their potential impact on the financial system) was negligible.
2. Lack of transparency: due to the high market shares of leveraged and inverse ETFs, the severity of this problem may grow in both countries but the potential threats are difficult to assess due to the short time span of the presence of these funds on the local financial markets (only ca. 5 years).
3. Risk of contagion and shock transmission between countries: over the most of the analysed time period there were no ETFs cross-listed in South Korea. Even though several ETFs were cross-listed in Japan (most of them near the end of the time period analysed), turnover of their shares remained very low. There are ETFs listed abroad that are based on Japanese or South Korean assets but their total net assets are low compared with the size of the respective markets for the underlying (e.g. capitalization of the Japanese or South Korean equity market). Therefore, the potential of this threat can be assessed as very low.
4. Negative impact on commodities markets: there are almost no commodity ETFs in either Japan or South Korea. Their share in the ETF market in both countries reached record-high levels in 2017 but it was still below or slightly above 1% (Deutsche Bank, 2017). As a result, the level of the risk is minimal.

To conclude, the ETF markets in Japan and South Korea in the time period analysed did not pose significant threats for financial stability. Apart from the analysis presented above, this is also evidenced by the lack of negative events which could be related to the development of ETF markets in the financial systems after the critical periods. However, in the coming years further development of ETF markets (especially an increasing total net assets of leveraged and inverse ETFs) may influence the stability of the financial systems.

6. Conclusions

The main aim of this paper was to provide in-depth insights into the issues associated with the selected categories of investment funds in South Korea and Japan over the period 2004–2017 focusing on the development patterns of the innovative group – ETFs. The potential substitution between ETFs and other investment funds has become one of the most-discussed issues in the financial industry. However, to the best of our knowledge, this is the first study to empirically verify the diffusion and substitution of ETFs in the market for investment funds with the application of monthly total net assets data and comparisons to both open-end and closed-end funds; moreover, it is the first detailed analysis for Japan and South Korea. The results of the analysis show that in these economies the ETF market has been developing (i.e. diffusion of ETFs has occurred) in terms of both total net assets of ETFs and their share in the total market for investment funds. One of the key factors in the ETF market development in both economies was the launch of leveraged and short ETFs (subcategories of synthetic ETFs which offer investors modified returns), which soon gained high popularity. These contributed significantly to the diffusion of ETFs as they gave investors access to new features, i.e. the ability to use leverage or short sales. In Japan, ETF market development has also been considerably boosted by the purchases made by the Japanese central bank.

The rate of diffusion and the phase of growth reached (according to the logistic growth model) differed in the two countries – in Japan by the end of the 2004–2017 period the ETF market was still in the early exponential growth stage, whereas in South Korea it closer to achieving the expected maximum saturation.

We have also checked substitution between equity ETFs and equity open-end funds. The results of this analysis clearly demonstrate that the process of "switching" from equity open-end funds into ETFs with similar exposure may be easily traced in both countries examined. Substitution processes were, however, gradual and reversals of the trajectories were noticed.

In addition, we have also considered the potential impact of ETFs on the local financial systems. Our results suggest that it is difficult to draw conclusions about such linkages – probably the most significant (yet still rather negligible) threats are the lack of transparency of new types of ETFs and decreasing turnover of Japanese ETFs in relation to their assets. On the whole, in the analysed time period ETF markets were too small to influence the financial systems.

Uncited references

Kwasnicki, 2015
Kwasnicki, 1994
PwC, 2016
Samsung Asset Management, 2016

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Appendix A. ETF diffusion patterns. Japan and South Korea. 2004–2017 and predictions.

Source: Authors' elaboration using IIASA software. Note: dotted line – empirical line; solid line – theoretical (modelled) line

Appendix B. Financial substitution patterns. Equity ETFs versus equity open-end funds in Japan and South Korea. Respective subsamples – FSP_2_Jap and FSP_2_Kor – and predictions until 2030.

Source: Authors' elaboration using IIASA software. Note: Fisher-Pry transformation applied for visualization. For Japan and South Kores, Fisher-Pry Y-axis range = 0.01–100.

References

Agapova, A., 2010. Conventional mutual index funds versus exchange-traded funds. J. Financ. Mark. 14, 323–343.
Aggarwal, R. and L. Schofield. "The growth of global ETFs and regulatory challenges." In Advances in Financial Economics, by J. Kose, A.K. Makhija and S.P. Ferris (Eds.), 77–102. Emerald Group Publishing Limited, 2014.
Amenc, N., Ducoulombier, F., Goltz, F., Tang, L., 2012. What are the risks of European ETFs?. In: EDHEC-risk Institute.
Baker, H.K., Filbeck, G. and H. Kiymaz. "Mutual funds and related investment vehicles: an overview." In Mutual Funds and Exchange-Traded Funds: Building Blocks to Wealth, by H.K. Baker, G. Filbeck, and H. Kiymaz (Eds.), 3–20. Oxford University Press, 2016.
Bekaert, G., Harvey, C.R., Lundblad, C., 2011. Financial openness and productivity. World Dev. 39, 1–19.
Ben-David, I., Franzoni, F.A., Moussawi, R., 2017. Exchange traded funds. Annual Review of Financial Economics 9, 169–189.
BlackRock, 2015. The Art of Indexing. BlackRock Advisors, London.
Calamia, A., Deville, L., Riva, F., 2013. Liquidity in European equity ETFs: what really matters?. GREDEG Working Paper Series 10, 1–26.
Chauhan, R., Kaur, H., Lechman, E. and A. Marszk. Big data analytics for ICT monitoring and development. In Catalyzing Development Through ICT Adoption: The Developing World Experience, by H. Kaur, E. Lechman and A. Marszk (Eds.), 25-36, Springer, 2017.
Claessens, S., Forbes, K., 2001. International Financial Contagion. Springer.
Deutsche Bank, 2015. Asia Pac Monthly ETF Insights October 2015. Deutsche Bank AG, Hong Kong.
Deutsche Bank, 2017. ETF Monthly Asia. October 2017. Deutsche Bank AG, London.
Deville, L. "Exchange Traded funds: history, trading and research." In Handbook of Financial Engineering, by M. Doumpos, P. Pardalos and C. Zopounidis (Eds.), 67–98. Springer US, 2008.
Diaz–Rainey, I., Ibikunle, G., 2012. A taxonomy of the 'Dark Side' of financial innovation: the cases of high frequency trading and exchange traded funds. Int. J. Entrep. Innov. Manag. 16, 51–72.
Diaz-Rainey, I., Ibikunle, G., Mention, A.-L., 2015. The technological transformation of capital markets. Technological Forecasting & Social Change 99, 277–284.
Dosi, G., Nelson, R.R., 1994. An introduction to evolutionary theories in economics. J. Evol. Econ. 4 (3), 153–172.
Ernkvist, M., 2015. The double knot of technology and business-model innovation in the era of ferment of digital exchanges: the case of OM, a pioneer in electronic options ex-changes. Technological Forecasting & Social Change 99, 285–299.
Essendorfer, S., Diaz-Rainey, I., Falta, M., 2015. Creative destruction in Wall Street's technological arms race: evidence from patent data. Technological Forecasting & Social Change 99, 300–316.
Ferri, R., 2009. The ETF Book: All You Need to Know About Exchange-Traded Funds. Wiley, Hoboken, NJ.
Fisher, J.C., Pry, R.H., 1972. A simple substitution model of technological change. Technol. Forecast. Soc. Chang. 3, 75–88.
Foucher, I., Gray, K., 2014. Exchange-traded funds: evolution of benefits, vulnerabilities and risks. In: Bank of Canada Financial System Review December. pp. 37–46.
Gastineau, G.L., 2010. The Exchange-Traded Funds Manual. John Wiley & Sons.
Geroski, P.A., 2000. Models of technology diffusion. Res. Policy 29 (4), 603–625.
Hehn, E., 2005. Introduction. In: Hehn, E. (Ed.), Exchange traded funds: structure, regulation and application of a new fund class, by. Springer, Heidelberg, pp. 1–6.
Hill, J., 2018. FinTech and the Remaking of Financial Institutions. Academic Press, (in press).
Hill, J.M., Nadig, D., Hougan, M., Fuhr, D., 2015. A Comprehensive Guide to Exchange-Traded Funds (ETFs). CFA Institute Research Foundation, Charlottesville, VA.
International Monetary Fund, 2011. Global financial stability report: durable financial stability. In: Getting There from Here, World Economic and Financial Surveys.
Investment Company Institute. 2017 Investment Company Fact Book. 2017. https://www.ici.org/pdf/2017_factbook.pdf (accessed November 10, 2017).
Johnson, B., Bioy, H., Garcia-Zarate, J., Choy, J., Gabriel, J., Rose, G., Kellett, A., 2012, May. Synthetic ETFs under the microscope: a global study. In: Morningstar ETF Research.
Kauffman, R.J., Liu, J., Ma, D., 2015. Innovations in financial IS and technology eco-systems: high-frequency trading in the equity market. Technol. Forecast. Soc. Chang. 99, 339–354.
Kaur, H., Lechman, E., Marszk, A., 2017. Financial markets diffusion patterns. The case of Mexican investment funds. Equilibrium 12 (1), 83–100.
Kosev, M., Williams, T., 2011. Exchange-traded funds. In: Reserve Bank of Australia Bulletin. March Quarter.
Kwasnicki, W., 2015. Logistic growth of the global economy and competitiveness of nations. Technol. Forecast. Soc. Chang. 80 (1), 50–76.

Kwasnicki, W., 1994. Technological Substitution Processes. An Evolutionary Model. Institute of Industrial Engineering and Management, Wroclaw University of Technology.
Kucharavy, D., De Guio, R., 2011. Logistic substitution model and technological forecasting. Procedia Engineering 9, 402–416.
Kudryashov, N.A., 2013. Polynomials in logistic function and solitary waves of nonlinear differential equations. Appl. Math. Comput. 219 (17), 9245–9253.
Lechman, E., 2015. ICT Diffusion in Developing Countries: Towards a New Concept of Technological Takeoff. Springer.
Lechman, E., Marszk, A., 2015. ICT technologies and financial innovations: the case of exchange traded funds in Brazil, Japan, Mexico, South Korea and the United States. Technol. Forecast. Soc. Chang. 99, 355–376.
Madhavan, A., 2016. Exchange-Traded Funds and the New Dynamics of Investing. Oxford University Press.
Mansfield, E., 1961. Technical change and the rate of imitation. Econometrica: Journal of the Econometric Society 29 (4), 741–766.
Marchetti, C., Nakicenovic, N., 1980. The Dynamics of Energy Systems and the Logistic Substitution Model. International Institute for Applied Systems Analysis.
Meyer, P., 1994. Bi-logistic growth. Technol. Forecast. Soc. Chang. 47 (1), 89–102.
Meyer, P.S., Yung, J.W., Ausubel, J.H., 1999. A primer on logistic growth and substitution: the mathematics of the Loglet Lab software. Technol. Forecast. Soc. Chang. 61 (3), 247–271.
Miranda, L., Lima, C.A., 2013. Technology substitution and innovation adoption: the cases of imaging and mobile communication markets. Technol. Forecast. Soc. Chang. 80 (6), 1179–1193.
Morris, S.A., Pratt, D., 2003. Analysis of the Lotka–Volterra competition equations as a technological substitution model. Technol. Forecast. Soc. Chang. 70 (2), 103–133.
Nakamura, Y., Sano, N., 2016. Owning Half of Japan's ETF Market Might Not Be Enough for Kuroda. In: www.bloomberg.com/news/articles/2015-10-28/owning-half-of-japan-s-etf-market-might-not-be-enough-for-kuroda, Accessed 19 March 2016.
Nakicenovic, N. "Technological substitution and long waves in the USA." In The Long-Wave Debate, by T. Vasko (Ed.), 76–103. Springer Berlin Heidelberg, 1987.
Naumenko, K., Chystiakova, O., 2015. An empirical study on the differences between synthetic and physical ETFs. International Journal of Economics and Finance 7 (3), 24–25.
Nikbakht, F., Pareti, K. and A.C. Spieler. "Exchange-traded funds." In Mutual Funds and Exchange-Traded Funds: Building Blocks to Wealth, by H.K. Baker, G. Filbeck, and H. Kiymaz (Eds.), 153–168. Oxford University Press, 2016.
Panourgias, N.S., 2015. Capital markets integration: a sociotechnical study of the development of a cross-border securities settlement system. Technol. Forecast. Soc. Chang. 99, 317–338.
PwC, 2016. ETF 2020: Preparing for a new Horizon. In: https://www.pwc.com/jg/en/publications/etf-2020-exchange-traded-funds-pwc.pdf, (accessed February 10, 2016).
Ramaswamy, S., 2011. Market structures and systematic risks of exchange-traded funds. In: BIS Working Papers. p. 343.
Rogers, E.M., 2010. Diffusion of Innovations. Simon and Schuster.
Rubino, J., 2011. Emerging threat funds?. CFA Magazine 22, 30–33.
Samsung Asset Management, 2016. Overview of Korean ETF Market. In: www.set.or.th/th/news/download/files/2553/OverviewofKoreanETFMarket.pdf, Accessed 30 March 2016.
Satoh, D., 2001. A discrete bass model and its parameter estimation. J. Oper. Res. Soc. Jpn. 44 (1), 1–18.
Seki, Y. "ETFs and REITs in Japan: innovation and steps for future growth." In New Financial Instruments and Institutions: Opportunities and Policy Challenges, by Y. Fuchita and R. Litan (Eds.), 15–58. Brookings Institution Press & Nomura Institute of Capital Markets Research, 2007.
Srinivasan, V., Mason, C.H., 1986. Technical note – nonlinear least squares estimation of new product diffusion models. Mark. Sci. 5 (2), 169–178.
Tokyo Stock Exchange, 2016. ETF ETN Annual Report 2016. Japan Exchange Group, Tokyo.
Urakabe, A., 2014. Domestic ETF market's rapid growth driven by short-term traders. Iakyara 197, 1–5.
Value Line. The Differences Between Mutual Funds, Closed-End Funds, and ETFs. 2010. http://www.valueline.com/Tools/Educational_Articles/Funds/The_Differences_Between_Mutual_Funds,_Closed-End_Funds,_and_ETFs.aspx (accessed 10.07.2017).
Wang, M.Y., Lan, W.T., 2007. Combined forecast process: combining scenario analysis with the technological substitution model. Technol. Forecast. Soc. Chang. 74 (3), 357–378.

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